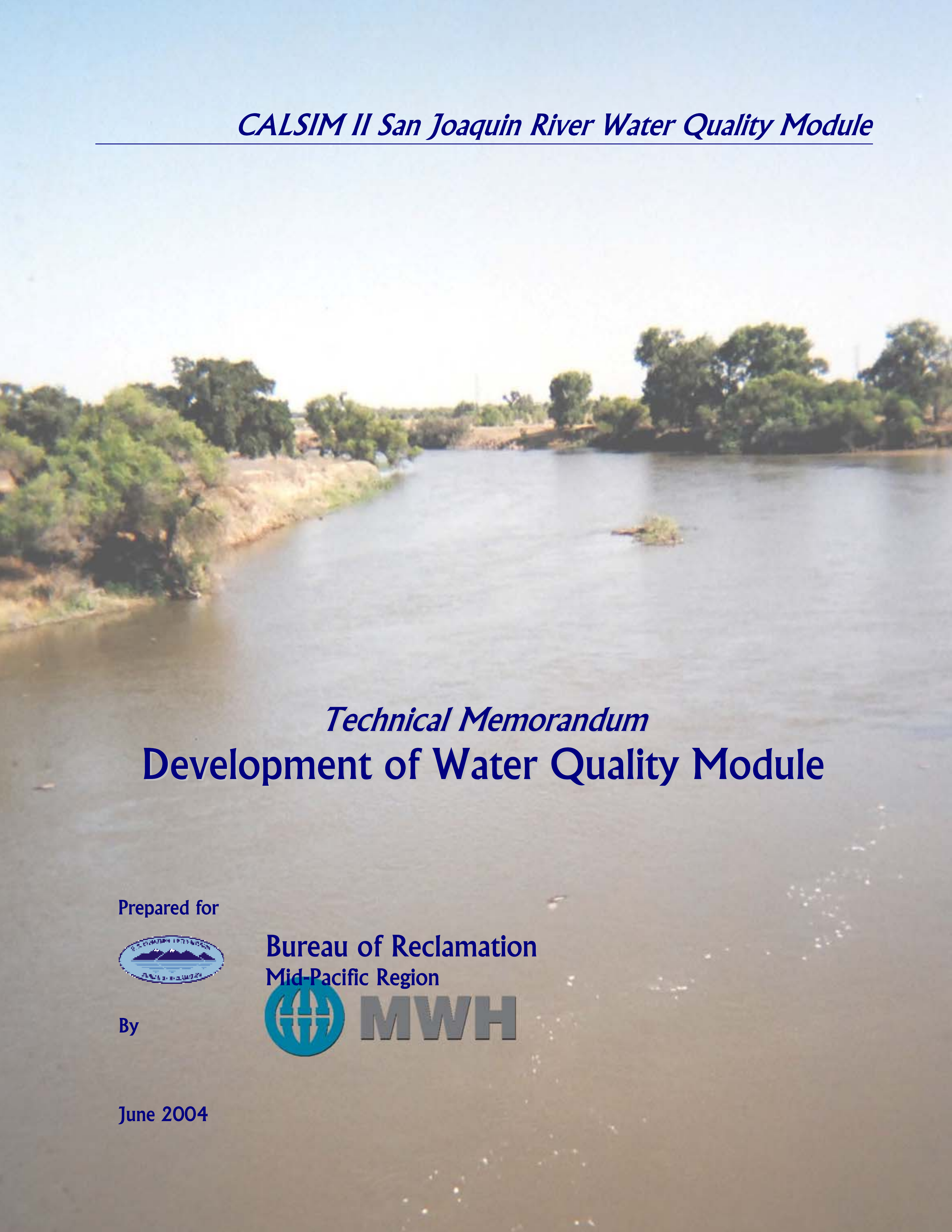

CALSIM II San Joaquin River Water Quality Module

Technical Memorandum

Development of Water Quality Module

Prepared for

Bureau of Reclamation
Mid-Pacific Region

By

MWH

June 2004

Cover Photo: San Joaquin River at Highway 132 near Vernalis, facing upstream on May 7, 2004
Photo Credit: Yung-Hsin Sun

EXECUTIVE SUMMARY

INTRODUCTION

This document summarizes the development of the Water Quality Module for the San Joaquin Valley of the CALSIM II model and provides detailed descriptions of what the Bureau of Reclamation (Reclamation) has achieved in improving salinity estimates at Vernalis through the refinement of the disaggregation methodology and the examination of additional EC data.

The overall structure of the document is as follows:

- Chapter 1 provides an introduction and background pertinent to the San Joaquin River water quality modeling effort and work from related projects;
- Chapter 2 includes the improvement of the disaggregation method, the reasons why this methodology was chosen and other modeling tools that were used to develop this method, and the structure of the Water Quality Module;
- Chapter 3 discusses the details of how the Westside flow was disaggregated. The Westside flow components include the accretion, Westside returns, depletion, non-project diversion, and the non-project return flows;
- Chapter 4 describes the methodology of selecting water quality parameters, EC assumptions for non-local creek flows, EC calibration for local creek inflow, and the model results.
- Chapter 5 provides the summary and recommendations for future Water Quality Module improvements.

BACKGROUND

The 1995 Water Quality Control Plan (WQCP) stipulated the south Delta salinity objectives are 700 µS/cm from April through August and 1000 µS/cm from September through March. The Water Right Decision 1641 (D1641) requires Reclamation to meet salinity standards at Vernalis. To determine whether the Delta salinity standards are in compliance requires the assessment of the water quality conditions not only in the Delta area, but also in upstream areas.

CALSIM II is a planning model that can be used to model the State Water Project (SWP) and the Central Valley Project (CVP) water resources planning, operations and water quality for the Central Valley from Shasta Dam to the service area of the Metropolitan Water District of Southern California.

The CALSIM II salinity estimation for the San Joaquin River relies on a single mass balance equation at Vernalis (September 30, 2002 Benchmark Study). The components required to compute the mass balance at Vernalis include flows and EC from Goodwin Dam, Westside return flows, accretion-depletion flows, and the San Joaquin River flow at Maze. The EC at Maze is a function of flow and season developed by regressing historical flow and EC values at Maze Bridge. This relationship requires updating to current conditions and is also problematic due to the lack of a reliable stage-flow relationship at Maze. Furthermore, reliance on this single relationship doesn't support exploring management options which change EC-flow relationships within the valley.

In 2002, Reclamation and the California Department of Water Resources jointly conducted a Delta-Mendota Canal Recirculation Feasibility Study (Recirculation Study) in order to comply with the D1641 Decision that required the improvement of the Vernalis water quality standard. The objective of the Recirculation Study was to evaluate the impacts of meeting the instream flow requirement and potential fisheries impacts at Vernalis by recirculating the Delta water through the Delta-Mendota Canal and the Newman Wasteway. Two different models, CALSIM II and DSM2-SJR, were used to simulate impacts on the hydrology and the water quality. Montgomery Watson Harza (MWH) developed a disaggregation method to provide a link between these two models.

In March 2003, Reclamation developed a new water quality algorithm called the Link-Node approach. This method intended to provide better estimation of the salinity at Vernalis. The Link-Node approach replaced the single equation at Vernalis and with a number of EC-flow relationships from Lander Avenue to Vernalis.

In late 2003, Reclamation also recognized the need to update the San Joaquin hydrology and the salinity estimation of the San Joaquin Valley. Reclamation initiated a contract with MWH to further extend the Link-Node approach and the disaggregation methodology using hydrology and operations update from the San Joaquin River Refinement and Documentation Project to develop a Water Quality Module for the Westside of the San Joaquin Valley in CALSIM II model.

OBJECTIVES

The module development process featured a detailed water quality data collection effort and extension of previously developed disaggregation and Link-Node approaches to improve EC-flow calculation along the San Joaquin River. The objectives of this Module development focused on:

- Increasing resolution in flow source and flow location through Westside flow disaggregation
- Improving the salinity estimate to provide more dynamic and accurate water quality computation along the San Joaquin River.
- Applying EC assumptions using available water quality information from previous studies and existing models.
- Providing an analysis too for New Melones operations planning.

SUMMARY OF FINDINGS

In this Water Quality Module, the single EC-flow equation at Vernalis was replaced with a series of salt-balance calculations from Lander Avenue to Vernalis through disaggregating the Westside flows into more refined flow components and assigning each disaggregated flow with EC value. This modification provides a dynamic water quality mechanism, which is an important improvement for estimating the salinity at Vernalis.

EC calculations for the San Joaquin River are dynamic and thus flexible in accommodating changes in flow and/or quality due to hydrologic updates (accretion/depletion inputs, land-use estimates, and groundwater usage) or changes in the system operation (reservoir operation, and implementation of water quality standards) in the San Joaquin Valley.

In the module, each disaggregated flow components required an associated EC value to achieve the salt balance computation. It is anticipated that as basin operations evolve and as water quality monitoring efforts continue in the San Joaquin region, there will be cause to review and possibly revise the salinity estimates to be consistent with these operational changes.

RECOMMENDATIONS

Based on the findings of this Water Quality Module, the model did provide improvement in estimating the salinity at Vernalis. However, in the EC-flow scatter plots for Vernalis, the EC values still show an overestimate for the months of February and March. These overestimate EC values may be caused by using the over simplified EC-flow relation for the Eastside tributaries and the refuges returns near the Mendota Pool.

The EC assumptions improvement and data revision are an ongoing effort. To reflect the latest reservoir operations and irrigation practices in the San Joaquin Valley, the following efforts can be taken to improve the Water Quality Module:

Mid-term effort:

- Use more accurate inputs from the Eastside tributaries and Eastside agricultural drains to refine water quality estimates.
- Update representative San Joaquin River Input-Output model (SJRIO) year-type inputs to reflect current operations by using SJRIO assumptions for simulation years after 1990.
- Develop location-dependent EC-TDS conversion factors to replace current conversion factors.
- Extend the module's upstream boundary from Lander Avenue to Mendota Pool to enable water quality analysis of changes in Mendota Pool operation.

Long-term effort:

- Incorporate Westside groundwater pumping information from WESTSIM and available groundwater quality information into the CALSIM II model. Incorporation of these data will change the water balance along the San Joaquin River and will require recalibrating CALSIM II and the Water Quality Module.
- Continue field monitoring program and data collection.
- Recalibrate the Water Quality Module with major changes in modeled San Joaquin River Basin operation, hydrology, and EC assumptions to maintain consistency in historical gage records and overall improvement in modeling resolution.

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CALSIM II SAN JOAQUIN RIVER WATER QUALITY MODULE

Technical Memorandum:

Development of the Water Quality Module

DRAFT

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Table of Acronym

1995 WQCP	1995 Water Quality Control Plan
μS/cm	microSiemen per centimeter
CALSIM II	California Simulation Model II
CFS	Cubic feel per second
CVP	Central Valley Project
CVRWQCB	California Regional Water Quality Control Board Central Valley Region
D-1641	Water Right Decision 1641
Delta	Sacramento-San Joaquin Delta
DMC	Delta-Mendota Canal
DSM2-SJR	Delta Simulation Model 2 – San Joaquin Boundary Extension
DWR	California Department of Water Resources
Eastside	Eastern side of San Joaquin River
EC	Electrical conductivity
IGSM	Integrated Groundwater and Surface Water Model
LOD	Level-of-development
Recirculation Study	Delta-Mendota Canal Recirculation Study
Reclamation	United States Department of Interior, Bureau of Reclamation
RM	River mile
SJR Package	CALSIM II San Joaquin River Refinement and Documentation
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAF	Thousand acre-feet
TDS	Total dissolved solids
VAMP	Vernalis Adaptive Management Plan
Water Quality Module	CALSIM II San Joaquin River Water Quality Module
Westside	Western side of San Joaquin River
WESTSIM	Westside Simulation Model
WRESL	Water Resources Engineering Simulation Language

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CHAPTER 1. INTRODUCTION

The California Simulation Model II (CALSIM II) is a regional planning model for the Central Valley Project (CVP), the State Water Project (SWP) and areas tributary to the Sacramento-San Joaquin Delta (Delta). Operations of the CVP-SWP system are influenced by water quality conditions in the lower San Joaquin River. The California State Water Resources Control Board (SWRCB) stipulates in Water Right Decision 1641 (D-1641) a water quality index for the San Joaquin River at Vernalis. The purpose of the San Joaquin River Water Quality Module (Water Quality Module) is to improve the CALSIM II salinity estimate at Vernalis by disaggregating the model flow representation on the western side of the river (Westside) into component parts. The Water Quality Module extends study efforts of the Delta-Mendota Canal Recirculation Feasibility Study (Recirculation Study) for flow disaggregation and the CALSIM II link-node approach for salinity estimation. It is also part of the 2004 CALSIM II benchmark studies improvement efforts, in which the CALSIM II hydrology and operations for the San Joaquin River Basin were updated (under another project, the CALSIM II San Joaquin River Refinement and Documentation, or SJR Package).

There are two components in the Water Quality Module: Westside flow disaggregation[1] (completed in December 2003) and water quality parameter selection for salinity calculation (completed in June 2004). This technical memorandum documents methodologies and assumptions of these two components in detail. Because the development of the Water Quality Module is closely associated with hydrologic assumptions in the SJR Package, frequent reference to the SJR Package documentation (Reclamation, 2004) is recommended.

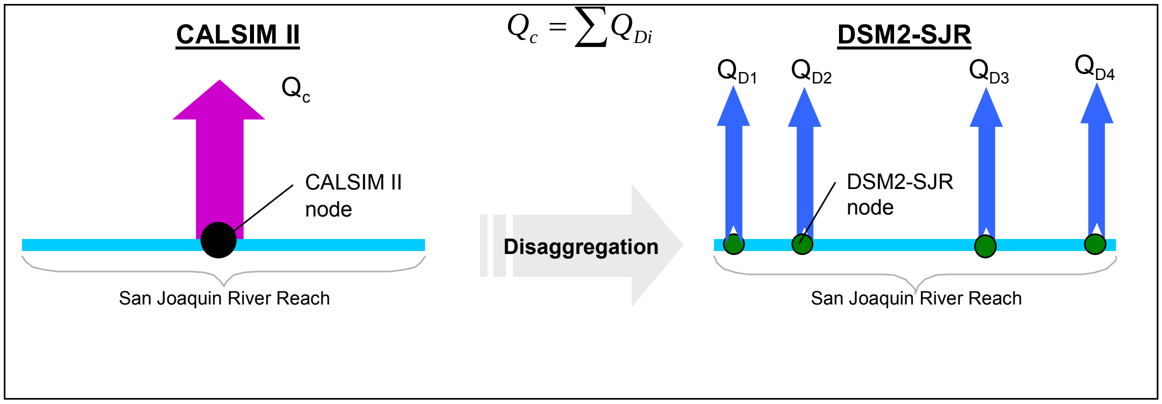
DELTA-MENDOTA CANAL RECIRCULATION FEASIBILITY STUDY

To comply with D-1641, the United States Department of the Interior, Bureau of Reclamation (Reclamation) and the California Department of Water Resources (DWR) conducted a Recirculation Study. The study was completed in August 2002; it evaluated impacts of meeting instream flow requirements at Vernalis per the San Joaquin River Agreement by recirculating Delta water through the Delta-Mendota Canal (DMC) and the Newman Wasteway (Reclamation, 2002a).

For the Recirculation Study, tools used for hydrologic and water quality analyses were CALSIM II and the Delta Simulation Model 2 – San Joaquin Boundary Extension (DSM2-SJR), respectively. Due to their distinctive modeling characteristics, a linkage was developed to transform CALSIM II outputs to DSM2-SJR hydrologic inputs for detailed salinity analysis (Reclamation, 2002b). This linkage disaggregates CALSIM II Westside flows into more refined DSM2-SJR components along the San Joaquin River from the Bear Creek confluence to Vernalis (**Figure 1-1**). (See Chapter 2 for more detail.)

[1] The Water Quality Module does not disaggregate the east-side inflows to the San Joaquin River, or Eastside flows.

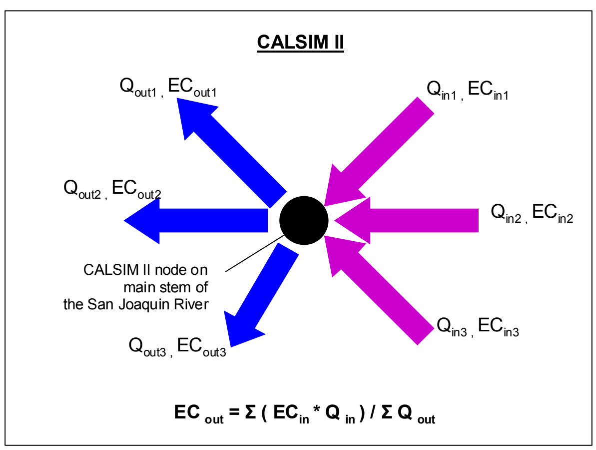
Figure 1-1. Linkage of CALSIM II and DSM2-SJR in Recirculation Study



CALSIM II Link-Node Approach

In March 2003, Reclamation developed a new water quality algorithm in CALSIM II, known as the link-node approach, to improve the salinity estimate at Vernalis (Reclamation, 2003). The 1995 Water Quality Control Plan (the 1995 WQCP) established water quality objectives at Vernalis in electrical conductivity (EC, unit in μS/cm or microS/cm). In the existing publicly released CALSIM II benchmark studies, dated September 30, 2002, EC estimates at Vernalis is based on a single modified Kratzer equation to relate EC to flow.[2] The link-node approach replaced the regression equation at Vernalis with salt balancing from Lander Avenue to Vernalis; it assigned EC values to inflows along the San Joaquin River under a revised representation of the San Joaquin Valley[3] as in the SJR Package (**Figure 1-2**). The comparison of link-node approach results against historical data showed a promising improvement from using the modified Kratzer equation.

Figure 1-2. CALSIM II Link-Node Approach



[2] The modified Kratzer equation relates EC to non-Westside flow at Maze through regression; then Vernalis water quality is derived from mass balancing Maze flow, Stanislaus River flow, and accretions/depletions below Maze.
[3] Update of San Joaquin Valley schematic is part of the SJR Package.

CALSIM II SAN JOAQUIN RIVER WATER QUALITY MODULE

The Phase 1 Progress Report from the link-node approach (Reclamation, 2003) suggested that disaggregation of Westside flows (equation 1-1) in conjunction with a salt balance may further improve the CALSIM II estimate of San Joaquin River salinity from Lander Avenue to Vernalis. In addition, CALSIM II would have a water quality resolution similar to DSM2-SJR. In September 2003, development of the Water Quality Module focused on modifying the Recirculation Study disaggregation mechanism to accommodate recent changes in CALSIM II: the San Joaquin Valley schematic and Westside return calculations. The module coverage is between Lander Avenue and Vernalis along the San Joaquin River. After assigning monthly EC values to each inflow, the module calculates salinity at CALSIM II nodes along the San Joaquin River from Lander Avenue to Vernalis through salt balancing (equation 1-2, as in the link-node approach). After completion of SJR Package in March 2004, EC assumptions in the Water Quality Module were modified to enhance water quality representation along the San Joaquin River.

Replacing the modified Kratzer equation with the Water Quality Module has changed CALSIM II results because the salinity estimate is now based on physical attributes from flows and diversions along the San Joaquin River. This approach altered the operation of New Melones Reservoir for Vernalis water quality requirements. To enable detailed water quality simulation in the future, the module also preserves the linkage with DSM2-SJR. (See Chapters 2 and 3 for more detail.) The Water Quality Module will be incorporated into a future version of the CALSIM II benchmark.

Disaggregation of Westside flow through water balancing:

$$Q_C = \Sigma Q_{WD} \tag{1-1}$$

Salt balance of Westside flow:

$$EC_C = \frac{\Sigma(EC_{WD} \times Q_{WD})}{\Sigma Q_C} \tag{1-2}$$

where

Q_C = CALSIM II Westside flow

Q_{WD} = Westside drainage flow

EC_C = EC of CALSIM II Westside flow

EC_{WD} = EC of Westside drainage flow

ORGANIZATION OF THIS TECHNICAL MEMORANDUM

This technical memorandum documents methodologies and assumptions for the Water Quality Module in detail; it is organized as follows:

- Chapter 1 provides the background on the Water Quality Module.
- Chapter 2 describes the disaggregation methodology of the Recirculation Study and the Water Quality Module.

- Chapter 3 documents flow disaggregation in the Water Quality Module.
- Chapter 4 provides methodology and assumptions for selecting water quality parameters, and EC-flow relationships of CALSIM II results against historical records.
- Chapter 5 contains a summary and recommendations for future module improvement.

CHAPTER 2. DISAGGREGATION METHODOLOGY

Westside inflows to the San Joaquin River are a serious water quality concern as the highly saline returns from Westside farmlands continuously drain into the San Joaquin River. The Recirculation Study and Water Quality Module both disaggregate the originally lumped CALSIM II Westside flows into their individual components: surface water returns (returns from surface diversion), pumped groundwater returns (returns from groundwater pumping), tile drainage, riparian diversions and returns, base groundwater accretions, seepage, and ephemeral streams. Selective assumptions from other surface water and groundwater models are used to facilitate the disaggregation.

This chapter gives an overview of CALSIM II and DSM2-SJR, and the reasons for disaggregating Westside flows. It then describes the disaggregation methodology of the Recirculation Study and the Water Quality Module.

CALSIM II AND DSM2-SJR

In the Recirculation Study, CALSIM II was the hydrological analysis tool while DSM2-SJR was used for water quality analysis. CALSIM II results of the monthly flow rate along the San Joaquin River provided the flow rate input for DSM2-SJR. A linkage is necessary to transfer CALSIM II output to DSM2-SJR.

CALSIM II

CALSIM II is a generalized water resources planning model developed by DWR and Reclamation. It simulates water supply operations of the SWP and CVP using a single time-step optimization technique (mixed integer liner programming). Model coverage stretches from Lake Shasta to the service area of the Metropolitan Water District of Southern California. CALSIM II represents the CVP-SWP system as a network of nodes and arcs. In each time-step, water is routed through the network according to various user-defined operating rules, objectives, and constraints. A channel arc may represent a river reach over 10 miles long. The current version of CALSIM II (September 2002) simulates monthly operation for a 73-year period based on historical hydrology: water years 1922 to 1994. Time-series inputs and outputs are in HEC-DSS format. Model objectives and constraints are specified using a dedicated language known as Water Resources Engineering Simulation Language (WRESL).

The version of CALSIM II used in the Recirculation Study is a July 2001 release for a 2001 level-of-development (LOD) (**Figure 2-1)**, hereafter referred to as *existing* CALSIM II, which simulates monthly operation for a 73-year period based on the historical hydrology, water year 1922 to 1994. CALSIM II used in the Water Quality Module (**Figure 2-2)**, hereafter referred to as *new* CALSIM II, was not publicly released in June 2004. The simulation period of the new CALSIM II is from water year 1922 to 1998, four years longer than the existing one. It has a new San Joaquin schematic and 2001 LOD. With a new San Joaquin schematic, the new CALSIM II has less redundant model components along the San Joaquin River. It also enhances the spatial detail of Eastside demand through land use based demands. **Table 2-1** summarizes the changes for the San Joaquin River from Lander Avenue to Vernalis.

Table 2-1. CALSIM II Model Schematic Comparison: "Existing" Against "New"

San Joaquin Valley Schematic: Model Components from Lander Avenue to Vernalis	Number in Existing CALSIM II	Number in New CALSIM II
San Joaquin River Nodes	18	8
San Joaquin River Flow Arcs		
Accretions	4	4
Westside Returns	5	5
Depletions	2	1
Non-Project Diversions	3	4
Non-Project Returns	3	3

DSM2-SJR

DSM2, developed by DWR, is a one-dimensional hydrodynamic and salt transport model for the Delta. DSM2 comprises a network of nodes and arcs, for which the channel geometry is specified. DSM2 has two modules: DSM2-HYDRO for hydrodynamics, and DSM2-QUAL for water quality. EC is used as a surrogate in salt transport and mass balance calculation. DSM2 covers the entire legal Delta region: the Sacramento River downstream of the City of Sacramento, the San Joaquin River downstream of Vernalis, and the Delta east of the Benicia Bridge. The simulation time-step is 15 minutes; a typical river reach is about 1 mile in length.

DSM2-SJR, developed in 2000, is an extension of DSM2 to the main stem of the San Joaquin River from the Bear Creek confluence to Vernalis (**Figure 2-3**). Each DSM2-SJR node approximately corresponds to a river mile (RM) of the San Joaquin River (see **Appendix A-1**). DSM2-SJR was developed because many Delta issues regarding water supply, water quality, and fishery are closely linked to conditions along the San Joaquin River. DSM2-SJR outputs include flow, stage, and water quality at selected reporting locations.

Reasons for Disaggregation

Because CALSIM II is a statewide water-balance planning model for CVP/SWP operation, its system resolution is low – each flow is an aggregate of regional flows. In contrast, DSM2-SJR, as a hydrodynamic water quality model of the San Joaquin River, requires detailed local flow and water quality information. Linking these two models requires addressing the difference in model resolution (**Table 2-2**). This is accomplished by disaggregating the CALSIM II flows.

CALSIM II accretions are an aggregated value of local creek inflow, runoff from precipitation, river-aquifer interaction and groundwater recharge for a river reach. The water quality of these accretion components varies considerably with geographic location and origin.

CALSIM II Westside return flows (returns) are proportional to surface water deliveries from the DMC. However, DMC water users also pump groundwater to supplement their surface water. Thus, Westside groundwater returns are a missing component in CALSIM II. CALSIM II Westside returns should be disaggregated into Westside surface returns and Westside groundwater returns to address the difference in water quality.

In CALSIM II, a single non-project diversion aggregates multiple riparian or appropriative diversions over a river reach. Therefore, it is necessary to disaggregate each CALSIM II non-project diversion into more refined locations. CALSIM II non-project returns are proportional to their corresponding non-project diversions. They also represent an aggregate of multiple riparian or appropriative returns over a river reach; therefore, each CALSIM II non-project return should be disaggregated to a number of smaller flows at various locations.

Table 2-2. Comparison of CALSIM II and DSM2-SJR

Model Characteristic	CALSIM II	DSM2-SJR
Time-step	1 month	15 minutes
Simulation	Water balance	• Hydrodynamics • Water quality
Model coverage of the San Joaquin River	Millerton Lake to Vernalis	Bear River to Vernalis
Length of a typical river reach	Over 10 miles	1 mile
Requires channel geometry	No	Yes
Input	• Monthly inflow • Operational rules	• Inflow rate • Inflow water quality
Output	• Flow rate • Water quality at Vernalis	• Flow rate • River stage • Water quality along the San Joaquin River

MODELS FOR DISAGGREGATION

Disaggregation is undertaken using assumptions and data from WESTSIM, San Joaquin River Input-Output Model (SJRIO), and geographic information system (GIS). The following is an overview of these models; details of their application in disaggregation are described in Chapter 3.

WESTSIM

WESTSIM, developed by Reclamation, is an application of the Integrated Groundwater and Surface Water Model (IGSM) for the Westside (**Figure 2-4**). IGSM is a distributed hydrologic model with groundwater, surface water, stream-groundwater interaction, and other hydrologic components. The three major processes simulated by IGSM include the following:

- Flow simulation on the land surface system
- Water movement through the stream system
- Fluid movement through the groundwater system, using a quasi three-dimensional finite element grid

WESTSIM contains 63 subregions that are defined by collections of finite elements to represent individual water districts or refuges. For each subregion, WESTSIM requires detailed inputs regarding land use, crop type, agricultural water use efficiency, river diversions, return flows, and aquifer characteristics. WESTSIM assumes all returns from a subregion flow[4] to a single stream node. Once calibrated, WESTSIM will simulate water use for the San Joaquin River Westside, including surface water diversions, groundwater pumping, groundwater recharge, and river-aquifer interaction.

In 2002, during the Recirculation Study, WESTSIM was undergoing calibration. WESTSIM was built on an older version of IGSM, which only allows monthly simulation. The original simulation period was from water years 1970 to 1993. In 2003, before calibration was completed, WESTSIM was upgraded to a new version of IGSM, known as IGSM2, which enables both daily and monthly simulations. The simulation period was extended from water years 1993 to 2000, but the individual subregion coverage and return flow locations remained unchanged. A new WESTSIM calibration is currently in progress and will not be completed until after development of the Water Quality Module, as estimated by the WESTSIM project manager.

SJRIO

In year 1987, SWRCB and the University of California, Davis, jointly developed SJRIO to predict the San Joaquin River water quality for regulatory purposes. SJRIO has provided results to the Central Valley Regional Water Quality Control Board (CVRWQCB) and the San Joaquin River Management Program Water Quality Subcommittee for year-type water quality predictions and management.

SJRIO is a monthly mass balance model that uses mass balance accounting to calculate monthly flow and salt loads of the San Joaquin River from Lander Avenue to Vernalis at specified river miles. SJRIO coverage is from RM 73 to 133. SJRIO inputs and outputs include flow and salt loading for tile drainage, groundwater flow, accretions/depletions, Westside surface/subsurface agricultural discharges, riparian diversions, and post-1914 appropriative diversions.

SJRIO has two kinds of running modes, historical (for calibration purposes) and year-type simulations (for planning purposes). Historical simulation requires historical data as input, whereas year-type simulation uses data representing four water year types of the San Joaquin River Basin: wet, normal, dry, and critical.[5] The simulation period for SJRIO1, the first version of SJRIO, is from water years 1977 to 1985 while SJRIO2 (updated in 1996) is from water years 1977 to 1995. The latest update was in year 2003; the historical simulation period of SJRIO3 is from water years 1977 to 2000. All versions of SJRIO have the same year-type inputs. Many of the SJRIO components have already been used in the development of DSM2-SJR; they both share the same river mile.

GIS

Reclamation has developed Arc-Info GIS shape files for schematics of existing CALSIM II, DSM2-SJR, and WESTSIM. These files spatially reference the nodes in a GIS environment (**Figure 2-5**).

[4] WESTSIM subregion return flow location is shown in Appendix A, Table A-6.
[5] More details for SJRIO year type are in Chapter 3.

DISAGGREGATION METHODOLOGY IN THE RECIRCULATION STUDY

For the Recirculation Study, CALSIM II and DSM2-SJR were linked through disaggregating each CALSIM II flow into one or more DSM2-SJR components. This disaggregation was coded in the CALSIM II WRESL files to write the disaggregated flows into an output DSS file that DSM2-SJR can access directly. With flows and water quality parameters as input, DSM2-SJR calculates San Joaquin River salinity. The linkage covers the San Joaquin River from the Bear Creek confluence to Vernalis.

The disaggregation maintains the overall water balance predicted by CALSIM II; that is, every month, each CALSIM II flow is equal to the total of its corresponding DSM2-SJR component flows. WRESL files for disaggregation do not affect the original CALSIM II calculation but simply post-process CALSIM II results to DSM2-SJR components.

Disaggregation in the Recirculation Study, incorporated into CALSIM II in July 2001, had a schematic that was the same as for the existing CALSIM II. Six types of CALSIM II variables were to be disaggregated to various DSM2-SJR variables; **Table 2-3** summarizes the disaggregation methodology of the Recirculation Study.

The following CALSIM II accretion illustrates how to use **Table 2-3**:

1. Each CALSIM II accretion variable is disaggregated into three groups of DSM2-SJR variables: subsurface agricultural discharges, groundwater base flows, and local creek inflow.

2. The quantity and location of each subsurface agricultural discharge and groundwater base flow are from SJRIO and DSM2-SJR. Flow volumes have been stored as state variables in the CALSIM II input file.

3. The location of local creek inflow, which is same as the CALSIM II accretion, is determined from GIS.

4. The local creek inflow quantity is obtained by subtracting subsurface agricultural discharges and groundwater base flows from the CALSIM II accretion. This inflow quantity is written to the CALSIM II output file.

The disaggregation used some of the SJRIO assumptions as inputs to supplement information that was not explicitly represented in CALSIM II, such as the monthly flow rate for tile drainage, groundwater base flow,[6] and Westside pumped groundwater return.

In the existing CALSIM II, deliveries to the DMC water users (CVP exchange and water service contractors of Westside) and their corresponding returns are aggregated based on their contract type, and not well correlated with their actual incurred locations. However, these DMC water users are explicitly represented by different subregions in WESTSIM, and each WESTSIM subregion has its return location. Therefore, the disaggregation applied the WESTSIM assumption of return location to improve resolution of DMC returns to the San Joaquin River.

[6] DWR has converted SJRIO output of groundwater base flow to DSM2-SJR input. (See Chapter 3 for more details.)

Table 2-3. Disaggregation of Recirculation Study

CALSIM Variables	Disaggregating CALSIM Variables for DSM2-SJR Use			
	Corresponding DSM2-SJR Variables	References Used to Achieve Mass Balance		
		For Location	For Quantity	For Allocation Percentage
Accretions	Subsurface agricultural discharges (SDF)	SJRIO	SJRIO	
	Groundwater base flow (BF)	DSM2-SJR	DSM2-SJR	
	Local creek inflow (CI)	GIS Grid	Forced balance	
Westside return flows (R)	DMC groundwater pumping return flow (GWR)	SJRIO	SJRIO	
	DMC surface water return flow (DMC)	CALSIM WESTSIM	Forced balance	
Depletions (D)	Groundwater seepage loss (SL)	GIS Grid	CALSIM	
Non-project demand diversions (D)	Non-project diversion (NPD)	SJRIO DSM2-SJR	CALSIM	SJRIO
Non-project return flows (R)	Non-project return flow (NPR)	SJRIO DSM2-SJR	CALSIM	SJRIO
East side inflows (C or R)	East side flows (ESF)	GIS Grid	CALSIM	

Source:

Table 1-1, *Delta-Mendota Canal Recirculation Study: Technical Memorandum: Linking CALSIM and DSM2-SJR for Delta-Mendota Canal Recirculation Study, Reclamation, August 2002*

DISAGGREGATION OF WATER QUALITY MODULE

The disaggregation methodology of the Water Quality Module is very similar to that of the Recirculation Study, except minor adjustments to accommodate the new CALSIM II. The disaggregation methodology disaggregates CALSIM II Westside flows to Westside drainage variables along the San Joaquin River between Lander Avenue and Vernalis; and also maintains the linkage between CALSIM II and DSM2-SJR. **Table 2-4** shows the disaggregation and following are the adjustments (shown as underlined items in **Table 2-4**):

- Remap every CALSIM II flow due to the change in its geographic coverage. That is, the flow location and its associated link-node variables must be redetermined.

- Verify CALSIM II Westside return locations against WESTSIM because the new CALSIM II regrouped deliveries to the DMC water users. (Other WESTSIM inputs or outputs will not be incorporated into this project due to its in-process calibration.)

- Re-evaluate the allocation percentage of each non-project diversion and return due to the change in geographic coverage. These two allocation patterns follow the weight of SJRIO dry-year non-project diversions and corresponding return flows.

- Assign each inflow along the San Joaquin River with an EC value for salinity calculation.

Although SJRIO[7] has been updated, the information it provided for the Water Quality Module is the same as for the Recirculation Study. This is because the SJRIO update was to extend the historical simulation period without revising any previous data.

For WESTSIM, because its calibration period was not compatible with development of this module, no uncalibrated output was incorporated in the module. However, this module used the WESTSIM assumptions for subregion return flow location as in the Recirculation Study to increase geographic resolution of Westside returns because this assumption did not change.

Table 2-4. Disaggregation of Water Quality Module

CALSIM II Variables	Westside Drainage Variables	References Used to Achieve Mass Balance		
		For Location	For Quantity	For Allocation Percentage
Accretion (I)	= Σ Tile drainage (TD)	SJRIO	SJRIO	
	+ Σ Groundwater base flow (BF)	DSM2-SJR	DSM2-SJR	
	+ Local creek inflow (CI)	GIS Grid	Forced balance	
Westside return (R)	= Σ Westside groundwater return flow (GWR)	SJRIO	SJRIO	
	+ Westside surface water return flow (SWR)	CALSIM WESTSIM	Forced balance	
Depletion (D)	= Groundwater seepage loss (SL)	GIS Grid	CALSIM	
Non-project diversion (D)	= Σ Non-project diversion (NPD)	SJRIO	CALSIM	SJRIO
Non-project return (R)	= Σ Non-project return flow (NPR)	SJRIO	CALSIM	SJRIO

Keys:
Σ = Summation of all relevant items.
Underlined items are items modified compared to the Recirculation Study.
Note:
Some names of link-node variable are different from DSM2-SJR variable of Table 2-2, but they represent the same kind of flows.

STRUCTURE OF WATER QUALITY MODULE

The Water Quality Module has two major components: disaggregation (flow calculation through flow balancing) and salt balance (water quality calculation through salt balancing). Time-series module inputs include EC values for all Westside drainage variables and monthly flows for flow components not represented explicitly in CALSIM II. To be compatible with DSM2-SJR, names for the Westside drainage variables have a prefix for the flow category (the abbreviations inside the brackets of **Table 2-4**) followed by the DSM2-SJR node. With this naming convention, DSM2-SJR can easily access the calculated flow and EC values from the Water Quality Module.

[7] WESTSIM and SJRIO application is discussed in *"Memorandum: WESTSIM and SJRIO Application in Westside Flow Disaggregation for the San Joaquin River Westside Drainage Model, MWH for Reclamation, October 24, 2003*

Some variables have three sets of results, for pulse flow, non-pulse flow, and weighted average periods[8]; they are indicated as "_p," "_np," and "_final" at the end of the variable name.

Module calculation is in new WRESL files inside the "Disaggregation" folder under directory "common\SanJoaquin\WaterQuality," and the module uses files named with the suffix "writeout" to export results to the output file (**Table 2-5**). New WRESL files are created from modifying existing files for the Vernalis water quality calculation (**Table 2-5**). Their file names end with "_Disag." Under this file organization, CALSIM II users can easily turn the Water Quality Module on or off by switching the "MAIN" WRESL file in the CALSIM interface.

Table 2-5. New WRESL Files for CALSIM II Variables Disaggregation

CALSIM II Component in Water Quality Module	Sub-Folder of "Disaggregation"	New WRESL Files
Accretion	Accretion	Accretion_Def.wresl EC_creek.table
Westside return	WestsideReturns	WS_Returns_Def.wresl WSReturnC1.wresl WSReturnC2.wresl WSReturnC3.wresl WSReturnC5.wresl WS_Returns_WriteOut.wresl
Depletion	Depletion	Depletion_Def.wresl
Non-project diversion	NP_Diversion	NPD_Flow.wresl NPD_EC.wresl NPD_WriteOut.wresl DSM2_NPD.table
Non-project return	NP_Return	NPR_Flow.wresl NPR_EC.wresl NPR_WriteOut.wresl DSM2_NPR.table
Modified CALSIM II Component for Water Quality Module	**Directory**	**New WRESL files from modifying existing ones**
Vernalis water quality calculation	Commom\ SanJoaquin\ WaterQuality	Vernalis_wqmin_Disag.wresl Vernalis_wqpulse_Disag.wresl Wq_defs_Disag.wresl EC_Table_MPool.table EC_Table_WestRtn.table
	Common\ SanJoaquin\ Various	Bounds_cycle6_Disag.wresl WQ_Bound_Disag.wresl

8 Vernalis Adaptive Management Plan (VAMP) studies pulse flow impacts on fisheries during a 31-day period in April and May. Pulse flow requirements have a big effect on the San Joaquin water supply operation. The pulse flow period in CALSIM II is assumed to be from April 16 to May 15; the non-pulse flow period is the rest of the year. The weighted average period gives averaged April and May results of pulse and non-pulse flow periods.

Figure 2-1. Existing CALSIM II San Joaquin Schematic of Recirculation Study

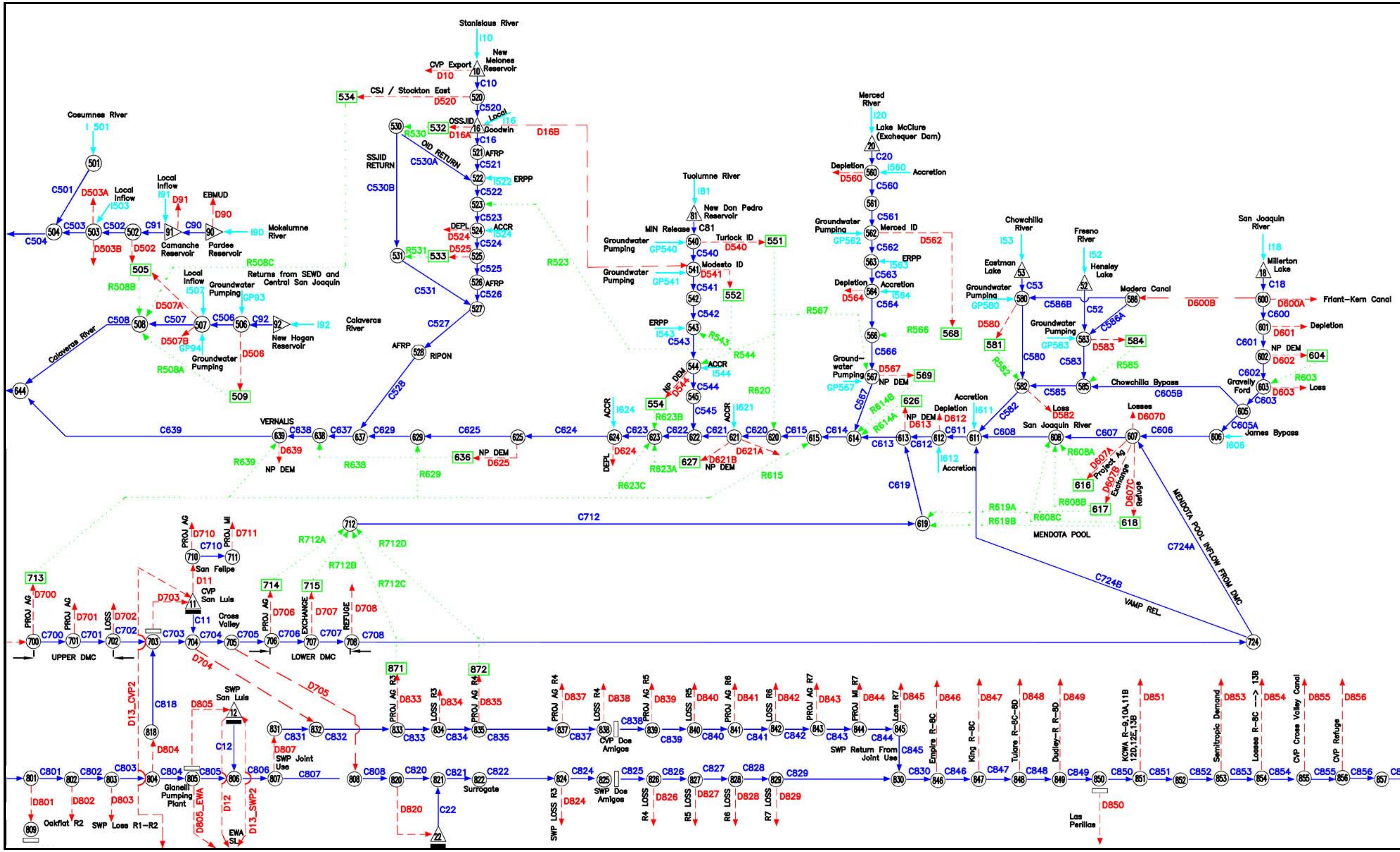


Figure 2-2. New CALSIM II San Joaquin Schematic used in Link-Node Approach and Water Quality Module

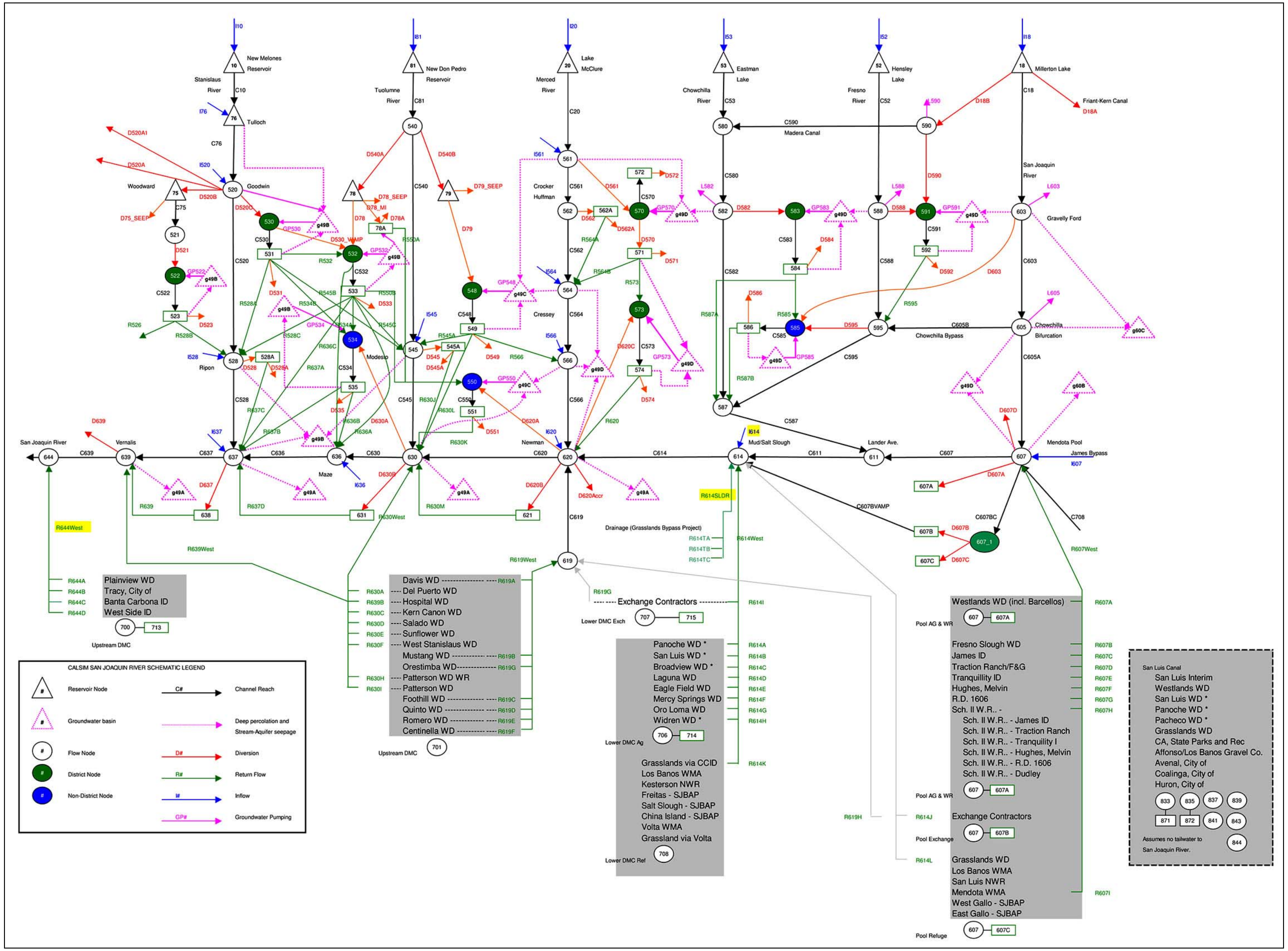


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Figure 2-3. DSM2-SJR Modeling Area

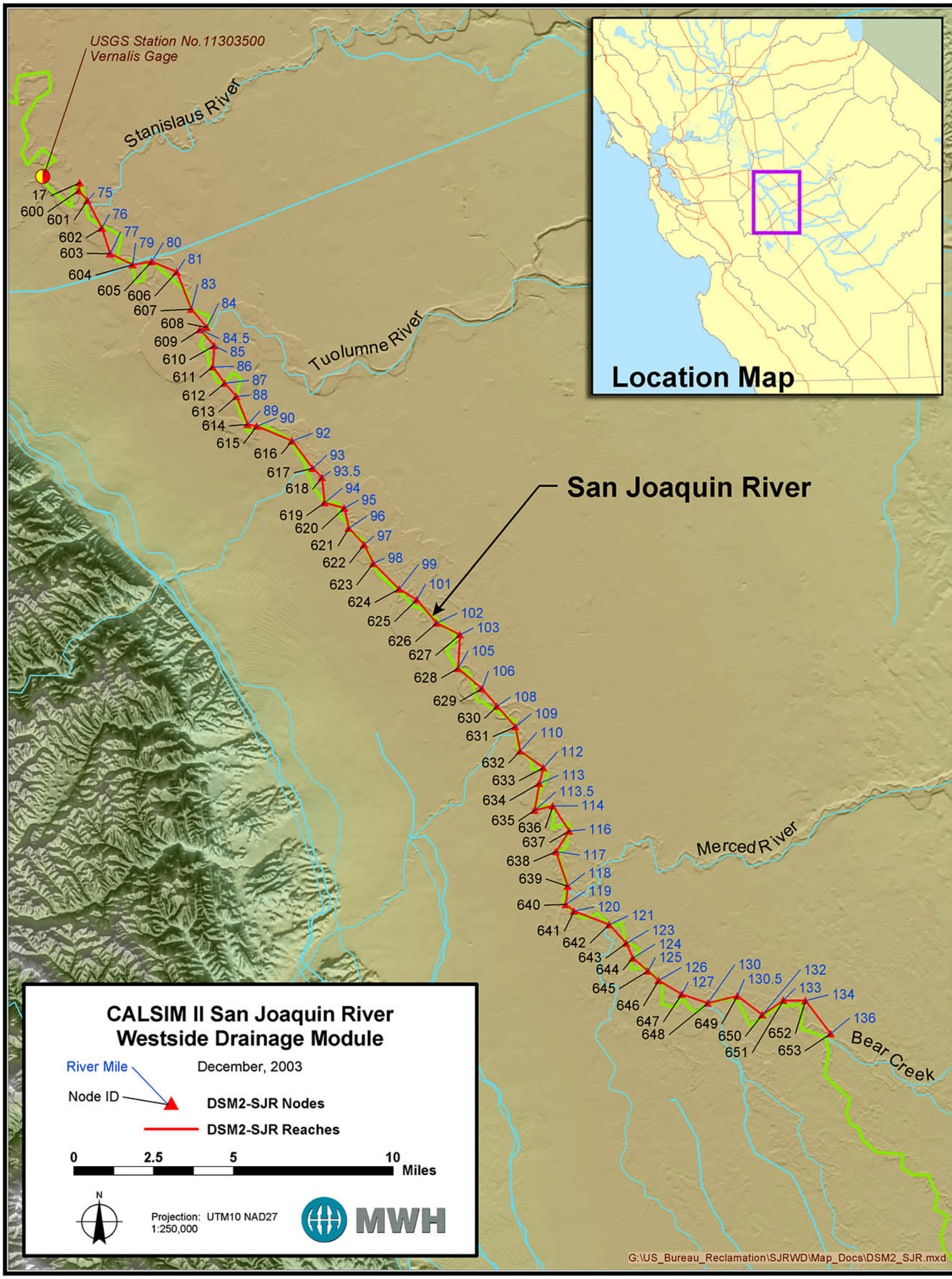


Figure 2-4. WESTSIM Subregions

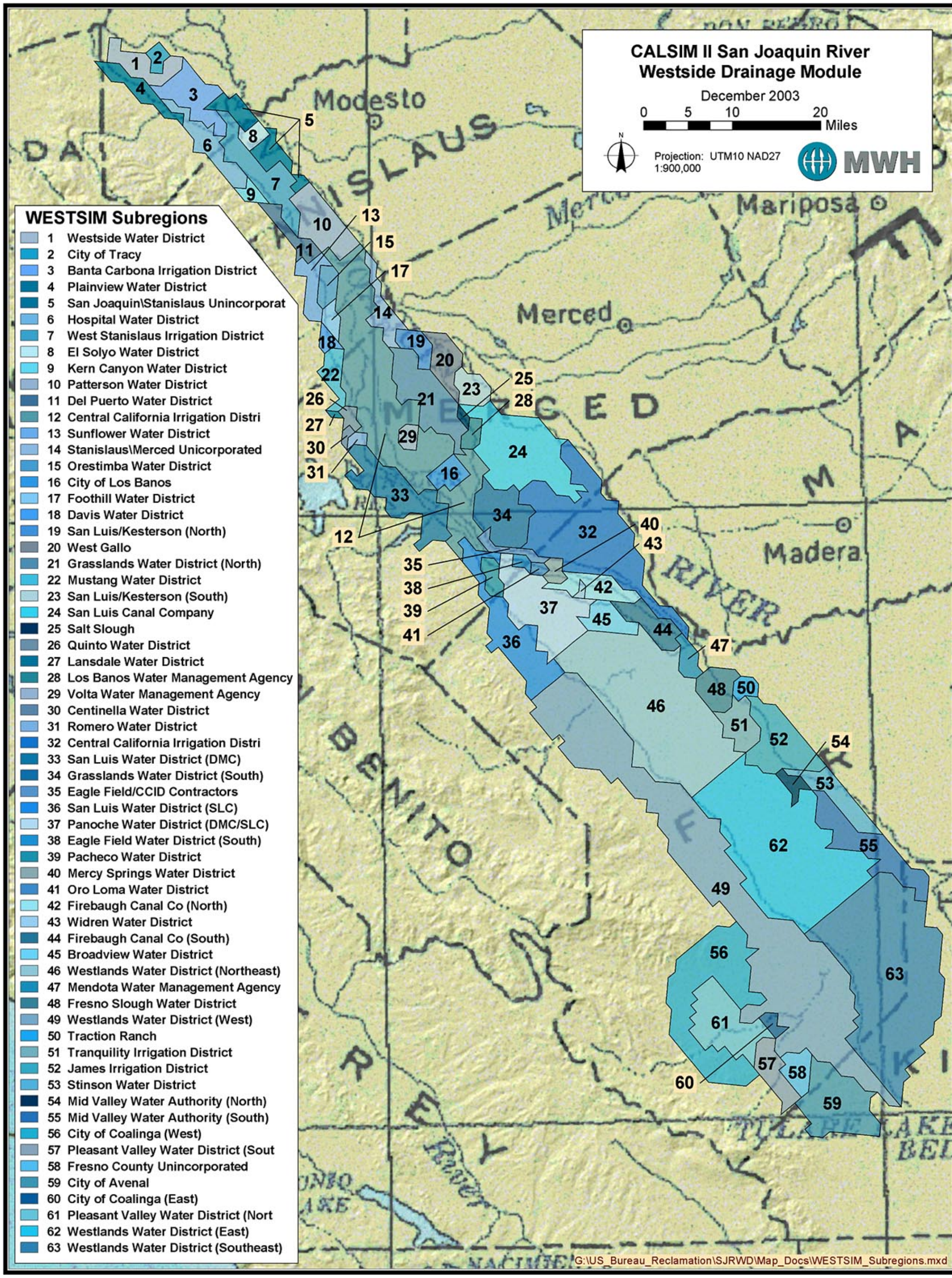
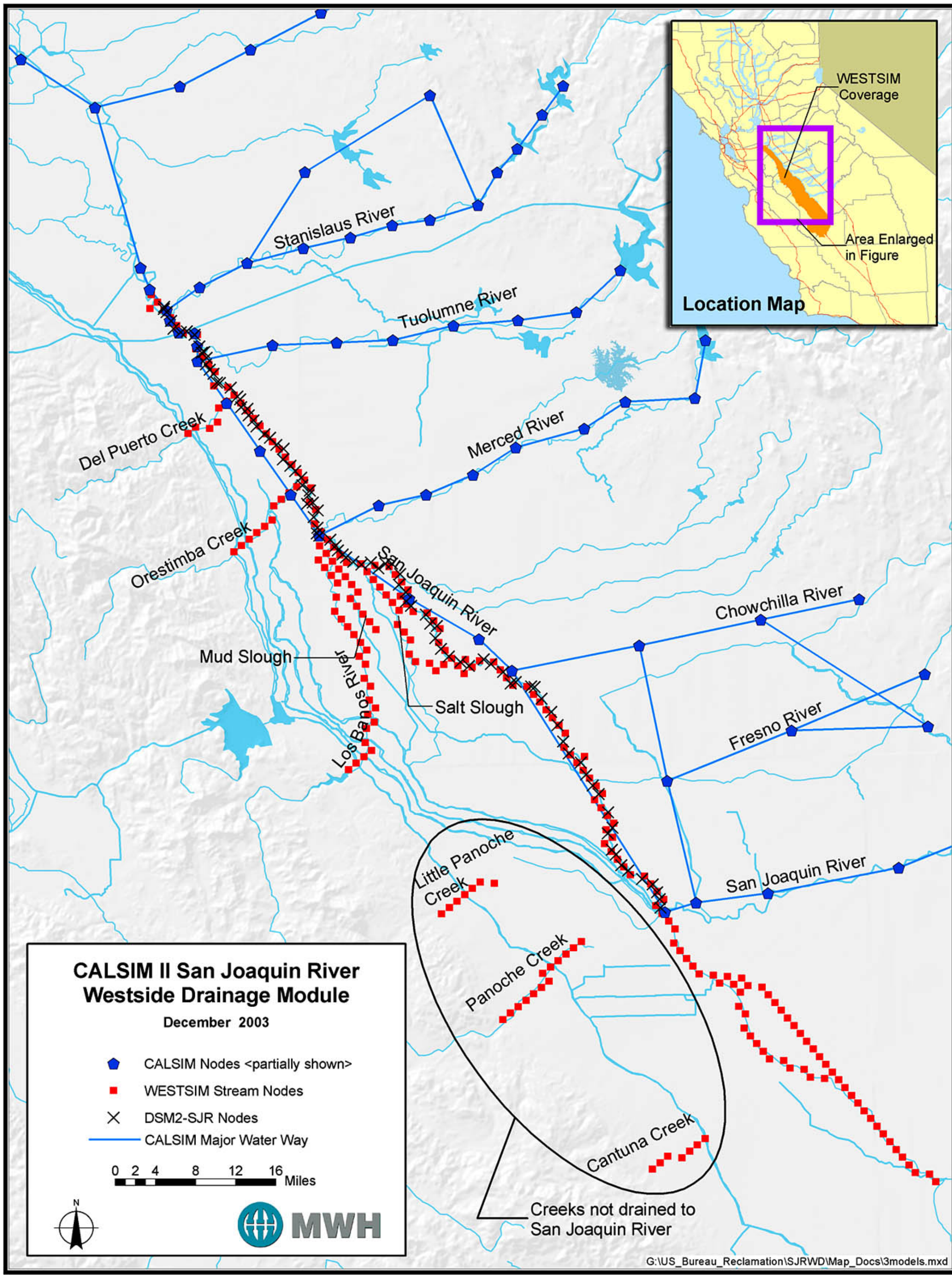


Figure 2-5. Schematics of Existing CALSIM II in San Joaquin Valley, DSM2-SJR, and WESTSIM



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CHAPTER 3. DETAILS OF WESTSIDE FLOW DISAGGREGATION

This chapter elaborates on the disaggregation methodologies and assumptions for the Water Quality Module, which are categorized in CALSIM II flow types: accretion, Westside return, depletion, non-project diversion, non-project return. The flow disaggregation is applied to Westside flows along the San Joaquin River between Lander Avenue and Vernalis.

ACCRETION

The Water Quality Module disaggregates the CALSIM II accretion flow type to multiple tile drainages, multiple groundwater base flows, and one local creek inflow. (Disaggregation details are given in the module methodology section.)

CALSIM II variable		Westside drainage variables
Accretion (I)	=	Σ Tile drainage (TD)
	+	Σ Groundwater base flow (BF)
	+	Local creek Inflow (CI)

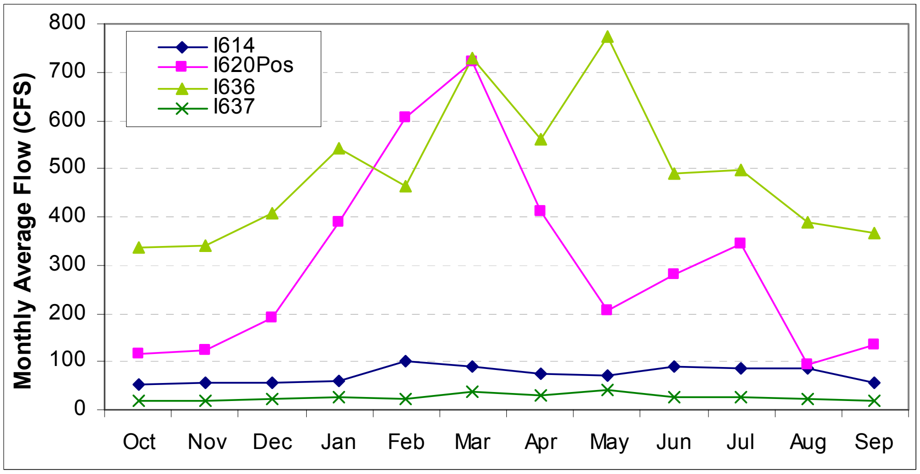
Although each CALSIM II accretion incurs at one single node, the node actually represents the net river gain (a combination of surface and subsurface flows) over a reach of the San Joaquin River. A total of four accretions with time-series inputs are summarized in **Table 3-1**. In the SJR Package, the monthly flow rate for each accretion (**Figure 3-1** shows the long-term average in cubic feet per second, or CFS) was calculated based on a water balance over a river reach or watershed using available gage data or other hydrologic information.

Table 3-1. CALSIM II Accretions on the San Joaquin River Between Lander Avenue and Vernalis

CALSIM II Accretion	Assumed Coverage in River Mile	Description
I614 =I614A+SLDR_614	118 to 133	I614A: Mud and Salt Slough base flows SLDR_614: San Luis Drain discharge
I620Pos	117 to 118	San Joaquin River inflow upstream of Merced River confluence
I636	77 to 117	San Joaquin River inflow between Merced River confluence and Maze gage station
I637	73 to 77	San Joaquin River inflow downstream of Maze to Vernalis

Source: \common\System\SystemTables_SJR\Inflow-table.wresl

Figure 3-1. CALSIM II Accretions: Long-Term Monthly Average Flow Rate



Westside Drainage Variables for Accretion

Westside drainage variables for accretion include tile drainage, groundwater base flow, and local creek inflow.

Tile Drainage

Tile drainage is subsurface inflow to the San Joaquin River from agricultural land[9]. The quantity and quality of this flow is highly related to agricultural practices. The SJRIO has 11 subsurface agricultural discharges, and the Water Quality Module includes 9 of them[10] as tile drainage on the western side of the river between Lander Avenue and Vernalis. In the SJRIO, each discharge is the product of a tile drainage factor (ranging from 0.65 to 0.85 acre-feet per acre per year) and its tile drainage acreage. Each discharge follows the same monthly pattern and the monthly quantity repeats every year (**Table 3-2**). The time-series for the tile drainage flow rate is an input to the Water Quality Module. (**Figure 3-2** shows the long-term average, maximum, and minimum in CFS.)

Groundwater Base Flow

Groundwater base flow consists of all subsurface flows except tile drainage. It is induced by the elevation difference in groundwater table and river stage. SJRIO outputs base flows every river mile, and DWR modified and applied this SJRIO result as DSM2-SJR input.[11] The monthly flow rate repeats every year independent of the water year type, and the flow rate time-series is an input to the Water Quality Module. (**Figure 3-2** shows the long-term average, maximum, and minimum in CFS.)

[9] Tile drainage is different from Westside returns and non-project return. Tile drainage is underground flow while the other two are overland flows from farmlands.
[10] The two locations excluded from the tile drainage of this module are discharges from Mud and Salt sloughs. This is because Mud and Salt sloughs are a combination of natural, surface agricultural, and subsurface agricultural drainage, which are different from the remaining flows.
[11] See Appendix A, Table A-7 and DSM2 documentation (DWR, 2001), for the conversions.

Local Creek Inflows

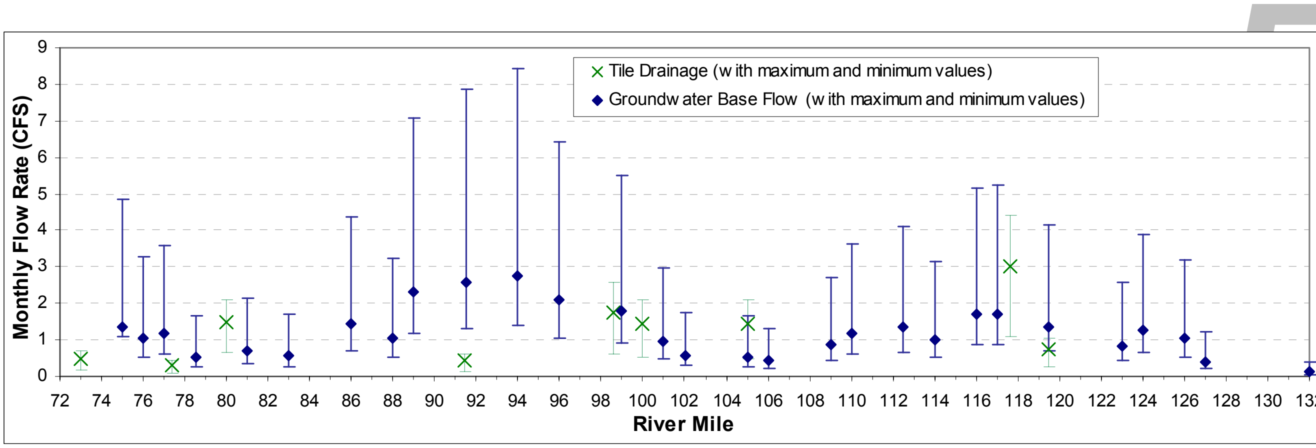
Local creek inflow is the CALSIM II accretion less assumed tile drainages and groundwater base flows. Same as accretion, it is incurred at a single location although it represents inflow along a river reach. The Water Quality Module calculates its monthly value as the closure term in a water balance between the CALSIM II accretion and the Westside drainage variables described above.

Table 3-2. SJRIO Monthly Tile Drainage for Every Year (acre-feet)

DSM2-SJR Node	17	603	650	616	623	624	628	638	641	Monthly Pattern
SJRIO River Mile	73.0	77.4	80.0	91.4	98.6	100.0	105.0	117.6	119.5	
October	24	15	71	21	87	71	71	149	36	7.0%
November	14	9	41	12	50	41	40	85	20	4.1%
December	10	6	39	9	37	31	30	64	15	2.9%
January	10	6	39	9	37	31	30	64	15	2.9%
February	20	13	79	18	74	61	60	128	31	5.9%
March	31	19	91	27	111	92	91	191	46	9.1%
April	41	26	122	36	149	122	121	255	61	12.0%
May	41	26	122	36	149	122	121	255	61	12.0%
June	41	26	122	36	149	122	121	255	61	12.0%
July	41	26	122	36	149	122	121	255	61	12.0%
August	37	23	111	33	136	112	111	234	56	10.9%
September	31	19	91	27	111	92	91	191	46	9.1%

Source: SJRIODAY2K\HSUB.DAT

Figure 3-2. Water Quality Module:
Monthly Flow Rate of Tile Drainage and Groundwater Base Flow
(Long-Term Average, Maximum, and Minimum)



Module Methodology

Water Quality Module methodology for accretion is shown in **Figure 3-3** and equation 3-1 and 3-2.

For each CALSIM II accretion, the Water Quality Module functions as follows:

1. Determine the river reach coverage of the accretion.

2. Determine the corresponding DSM2-SJR node where accretion is incurred from the GIS grid. This node is the local creek inflow location.

3. Identify all the tile drainages and groundwater base flows within the river reach.

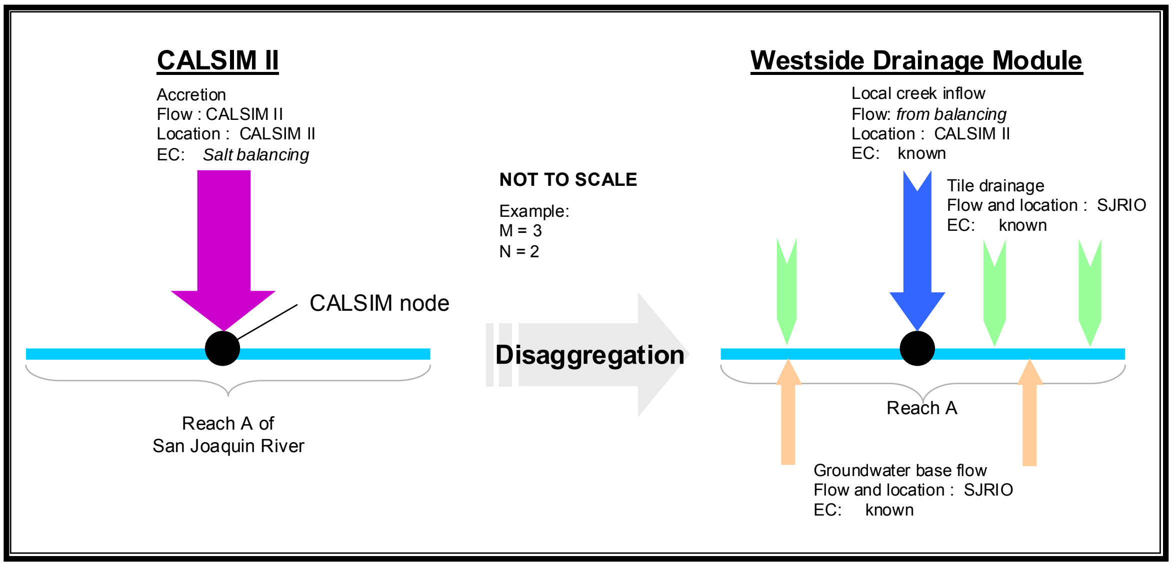
4. Use equation 3-1 to calculate the monthly local creek inflow from a water balance. Monthly flows for tile drainage and groundwater base flow are inputs to the module.

5. Use equation 3-2 to calculate the EC of accretion through an EC balance. Monthly EC values for all Westside drainage flows are inputs to the module.

6. Apply the accretion EC value from Step 5 to salt balancing along the San Joaquin River.

Table A-1 of **Appendix A** shows disaggregation details of the CALSIM II accretions.

Figure 3-3. Water Quality Module Methodology: Accretion



$$Q_I^A = \sum_{m=1}^{M} Q_{(TD,m)}^A + \sum_{n=1}^{N} Q_{(BF,n)}^A + Q_{CI}^A \quad (3\text{-}1)$$

$$EC_I^A = \frac{\sum_{m=1}^{M}\left(EC_{(TD,m)}^A \times Q_{(TD,m)}^A\right) + \sum_{n=1}^{N}\left(EC_{(BF,n)}^A \times Q_{(BF,n)}^A\right) + \left(EC_{CI}^A \times Q_{CI}^A\right)}{Q_I^A} \quad (3\text{-}2)$$

where

A	=	Reach A of San Joaquin River
I	=	Accretion arc
TD	=	Tile drainage arc
BF	=	Groundwater base flow arc
CI	=	Local creek inflow arc
M	=	Total number of tile drainage arcs

N	=	Total number of base flow arcs
Q_I^A	=	Monthly flow rate of CALSIM II accretion in reach A
$Q_{(TD,m)}^A$	=	Monthly flow rate of the m[th] tile drainage arc in reach A
$Q_{(BF,n)}^A$	=	Monthly flow rate of the n[th] groundwater base flow arc in reach A
Q_{CI}^A	=	Monthly flow rate of local creek inflow in reach A
EC_I^A	=	Monthly EC value of CALSIM II accretion in reach A
$EC_{(TD,m)}^A$	=	Monthly EC value of the m[th] of tile drainage arc in reach A
$EC_{(BF,n)}^A$	=	Monthly EC value of the n[th] of groundwater base flow arc in reach A
EC_{CI}^A	=	Monthly EC value of local creek inflow in reach A

WESTSIDE RETURN

The Water Quality Module disaggregates one CALSIM II Westside return to multiple Westside groundwater returns and one Westside surface water return. (Details are provided in the module methodology section.)

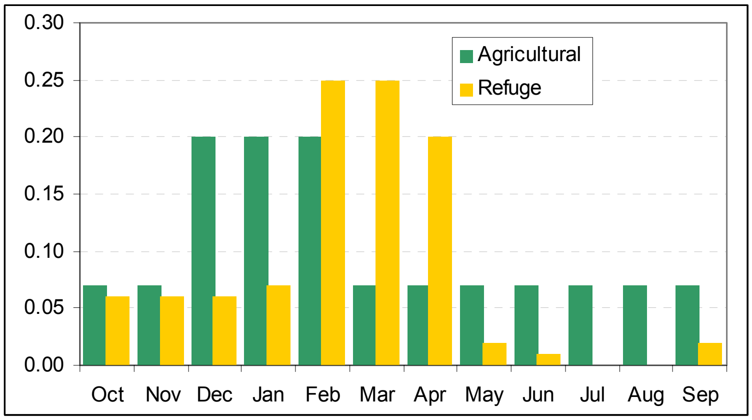
CALSIM II variable		Westside drainage variables
Westside return (R)	=	Σ Westside groundwater return (GWR)
	+	*Westside surface return (SWR)*

In CALSIM II, Westside returns are returns from CVP agricultural and refuge contractors who divert DMC water; portions of these diversions drain back to the San Joaquin River directly or indirectly. From Lander Avenue to Vernalis, four CALSIM II Westside return arcs enter the San Joaquin River; each is an aggregate of returns from various CVP contractors (**Appendix A, Table A-8**). CALSIM II assumes that return from each contractor is proportional to its DMC delivery.[12] The return factor depends on the type of CVP contract and the month (**Figure 3-4**), but some contractors have zero returns. Among these CVP contractors, Exchange Contractors has two delivery arcs and two return locations; the rest have one. The Westside return logic is coded in WRESL files contained in the "*ReturnFlows*" folder under *"common\SanJoaquin\"* directory.

In reality, Westside agricultural demands are met with both groundwater and surface water. CALSIM II, lacking dynamic simulation of groundwater use, assumes that Westside returns are only a function of DMC water usage. Thus, factors in **Figure 3-4** do not represent Westside irrigation efficiency. Since groundwater returns are of higher salinity than surface water returns, it is essential to explicitly represent groundwater returns in the San Joaquin River water quality estimation.

[12] Each CALSIM II DMC delivery arc is an aggregate of deliveries to several contractors. Delivery to an individual contractor is proportional to the weight of its annual CVP contract amount in that delivery arc.

Figure 3-4. CALSIM II Assumption:
Monthly Return Factors for Westside DMC Delivery



Source: \common\SanJoaquin\ReturnFlows\WestSideReturns.wresl

Westside Drainage Variables for Westside Returns

Westside drainage variables for Westside returns include Westside groundwater and surface water returns.

Westside Groundwater Return

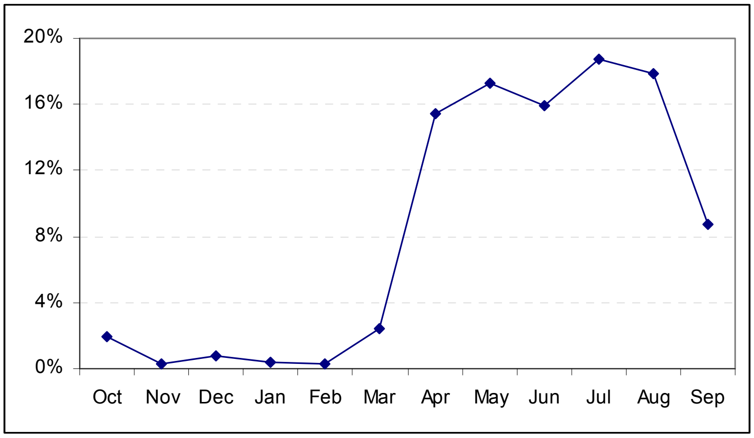
Westside groundwater returns are the assumed surface water returns from Westside pumped groundwater. SJRIO used historical records of water and power usage for water years 1961 to 1977 to develop average groundwater pumping data for the four SJRIO year types: wet, normal, dry, and critically dry. It assumes 30 percent of pumped groundwater returns to the San Joaquin River. SJRIO file *"HWSF.dat"* stores year-type annual groundwater pumping for each township (**Table 3-3**); SJRIO file *"DWSF.dat"* stores the monthly pumping pattern for all townships (**Figure 3-5**), and the return factor for pumped groundwater at specific river mile for each township (**Table 3-4**). Full natural flow data from the United States Geological Survey (USGS) were used to identify the SJRIO year-type[13] for water years 1922 to 1998 (**Appendix A, Table A-9**). The year-type monthly Westside groundwater returns at various river miles are then calculated and applied to the 77-year simulation period based on the SJRIO year-type for each year. The long-term monthly average flow rate of Westside groundwater returns along the San Joaquin River is shown in **Figure 3-6**.

[13] Page C-5 of SWRCB, 1997 has the definition of the SJRIO year-type (same as year types for the San Joaquin River Basin in Basin Plan of CVRWQCB):

Year Type	Total annual unimpaired flow (TAF)	Total annual unimpaired flow for years following critical years (TAF)
Critical	< 3,366	< 4,134
Dry	3,366 < x < 4,134	4,134 < x < 5,315
Normal	4,134 < x < 7,382	5,315 < x < 7,382
Wet	> 7,382	> 7,382

In the Water Quality Module, it is assumed that San Joaquin River basin unimpaired flow is the total unimpaired flows of the San Joaquin River below Friant Dam (SJF), Stanislaus River below Goodwin Dam (SNS), Tuolumne River below La Grange Dam (TLS), and Merced River near Merced Falls (MRC). These unimpaired flow data were downloaded from the California Data Exchange Center; acronyms in parentheses are the station symbols.

Figure 3-5. SJRIO Monthly Groundwater Pumping Pattern of Each Township



Source: SJRIO\SJRIODAY2K\DWSF.DAT

Figure 3-6. Water Quality Module: Long-term Average Monthly Flow Rate of Westside Groundwater Return (with Maximum and Minimum Values)

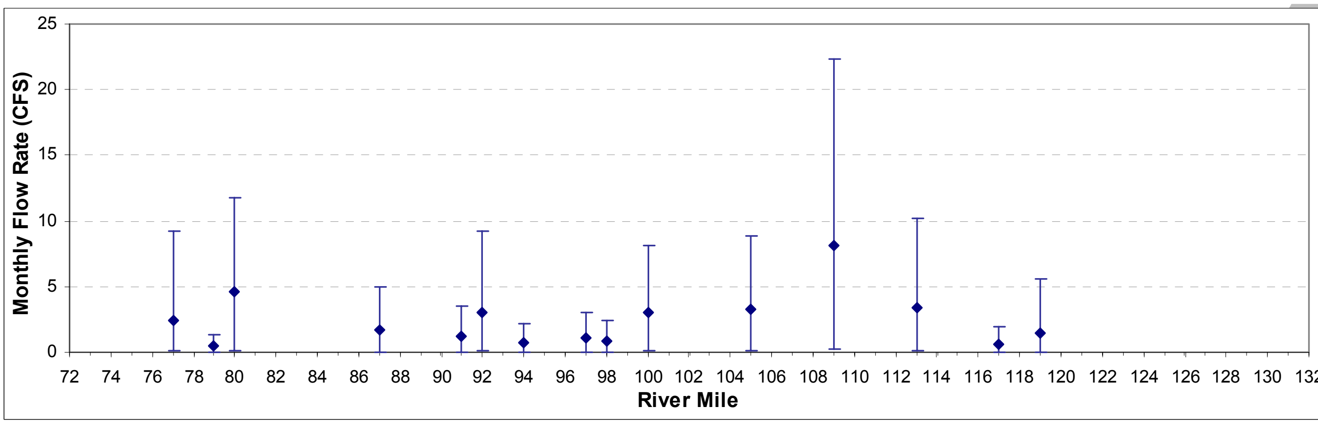


Table 3-3. SJRIO Year-Type Annual Groundwater Pumped by Township

Year Type	Township Groundwater Pumping (acre-feet)												
	3S/6E	3S/7E	4S/6E	4S/7E	4S/8E	5S/6E	5S/7E	5S/8E	6S/7E	6S/8E	6S/9E	7S/8E	7S/9E
Critical	3,172	1,580	10,500	7,753	407	462	14,200	3,918	822	21,700	663	21,700	1,445
Dry	8,725	822	11,400	5,835	449	377	19,300	3,918	886	27,000	1501	25,200	5,200
Normal	4,059	1,338	8,895	3,930	361	390	12,650	3,450	643	22,300	650	17,800	2,257
Wet	4,593	560	9,960	4,219	309	472	13,700	3,563	829	21,100	764	20,400	1,987

Source: SJRIO\SJRIODAY2K\HWSF.DAT

Table 3-4. SJRIO Township Pumped Groundwater Return Factors and Locations Along the San Joaquin River

River Mile	DSM2-SJR Node	Pumped Groundwater Return Factors for Townships												
		3S/6E	3S/7E	4S/6E	4S/7E	4S/8E	5S/6E	5S/7E	5S/8E	6S/7E	6S/8E	6S/9E	7S/8E	7S/9E
119	640												0.03	0.21
117	638											0.02	0.02	0.02
113	635											0.11	0.11	0.08
109	631										0.15	0.18	0.12	
105	628										0.08		0.03	
100	624								0.11	0.08	0.08			
98	623							0.02	0.08	0.09				
97	622							0.03	0.08	0.11				
94	619							0.03	0.03	0.03				
92	617					0.15	0.03	0.15	0.02					
91	616				0.02	0.15	0.03	0.05						
87	612				0.15		0.09	0.03						
80	605		0.03	0.27	0.12		0.15							
79	604		0.05	0.02	0.02									
77	603	0.3	0.23	0.02										

Source: SJRIO\SJRIODAY2K\DWSF.DAT

Westside Surface Water Return

Westside surface water returns are returns from DMC deliveries. The Water Quality Module calculates its monthly value through a water balance. Return locations are from WESTSIM, as WESTSIM associates subregions with CVP contractors, and each subregion has one return flow location (**Appendix A, Table A-6**).

Module Methodology

Water Quality Module methodology for Westside return is shown in **Figure 3-7** and equations 3-3 through 3-6.

For each CALSIM II Westside return, the Water Quality Module functions as follows:

1. Group all returns from CVP contractors with the same WESTSIM return location into one sub-return. The main return is a summation of its sub-returns as in equation 3-3. For example, R630West has five WESTSIM return locations, and therefore, five sub-returns.

2. Determine the river reach coverage of each sub-return.

3. Determine the corresponding return location in DSM2-SJR through the GIS grid. This node is the Westside surface return location of each sub-return.

4. Identify all Westside groundwater returns within the same river reach.

5. Use equation 3-4 to calculate the monthly Westside surface returns through a water balance. Monthly flows of Westside groundwater returns are module inputs.

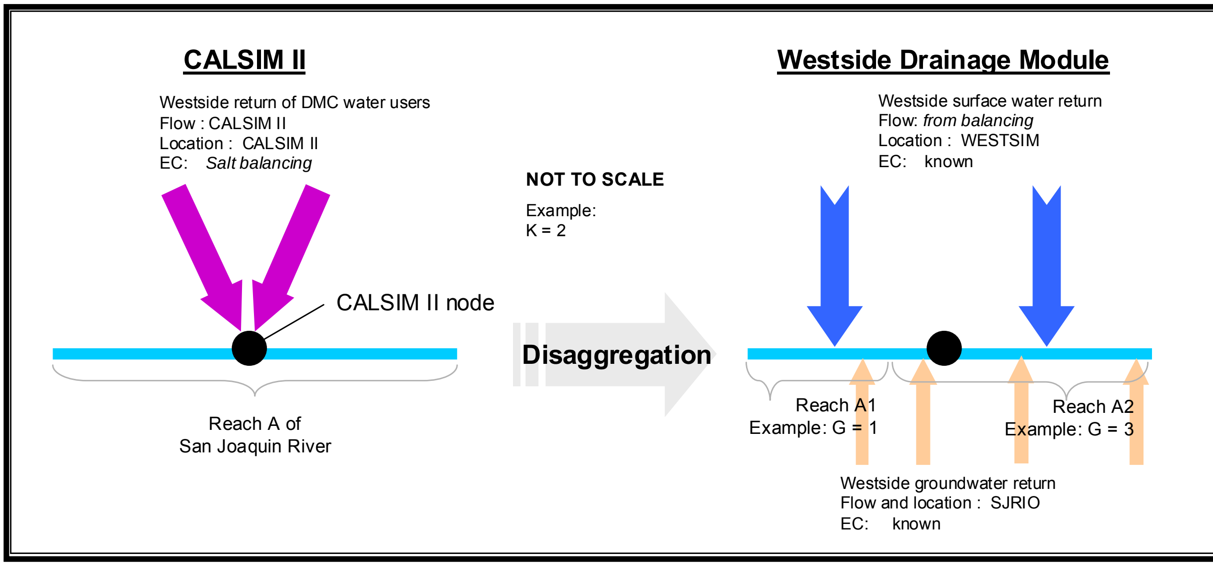
6. Use equation 3-5 to calculate the EC of sub-returns through salt balancing. Monthly EC values of all Westside drainage flows are module inputs.

7. Use equation 3-6 to calculate the EC of the main return.

8. Apply the Westside return EC value from Step 7 to salt balancing along the San Joaquin River.

Table A-2 of **Appendix A** shows disaggregation details of Westside return flows.

Figure 3-7. Water Quality Module Methodology: Westside Returns



$$Q_R^A = \sum_{k=1}^{K} Q_R^{(A,k)} \qquad 3\text{-}3$$

$$Q_R^{(A,k)} = \sum_{g=1}^{G} Q_{(GWR,g)}^{(A,k)} + Q_{SWR}^{(A,k)} \qquad 3\text{-}4$$

$$EC_R^{(A,k)} = \frac{\sum_{g=1}^{G}\left(EC_{(GWR,g)}^{(A,k)} \times Q_{(GWR,g)}^{(A,k)}\right) + \left(EC_{SWR}^{(A,k)} \times Q_{SWR}^{(A,k)}\right)}{Q_R^{(A,k)}} \qquad 3\text{-}5$$

$$EC_R^A = \frac{\sum_{k=1}^{K}\left(EC_R^{(A,k)} \times Q_R^{(A,k)}\right)}{Q_R^A} \qquad 3\text{-}6$$

Where

A	=	San Joaquin River Reach A
R	=	CALSIM II Westside return arc
GWR	=	Westside groundwater return arc
SWR	=	Westside surface return arc
K	=	Total number of sub-reaches in a river reach
G	=	Total number of Westside groundwater return arcs
Q_R^A	=	Monthly flow rate of CALSIM II Westside return for reach A

$Q_R^{(A,k)}$	=	Monthly flow rate of CALSIM II Westside return for sub-reach k of reach A
$Q_{(GWR,g)}^{(A,k)}$	=	Monthly flow rate of the gth Westside groundwater return for sub-reach k of reach A
$Q_{SWR}^{(A,k)}$	=	Monthly flow rate of Westside surface return for sub-reach k reach A
EC_R^A	=	Monthly EC value of CALSIM II Westside return for reach A
$EC_R^{(A,k)}$	=	Monthly EC value of CALSIM II Westside return for sub-reach k of reach A
$EC_{(GWR,g)}^{(A,k)}$	=	Monthly EC value of the gth Westside groundwater return for sub-reach k of reach A
$EC_{SWR}^{(A,k)}$	=	Monthly EC value of Westside surface return for sub-reach k of reach A

DEPLETIONS

Depletion represents stream seepage to the underlying groundwater basin. Since only one depletion occurs along the San Joaquin River in CALSIM II, *D620Accr* at the Merced River confluence, the Water Quality Module directly converts this CALSIM II depletion to one Westside drainage variable, seepage loss.

CALSIM Variable		DSM2-SJR Variable
Depletions (D)	=	Seepage loss (SL)

Westside Drainage Variable for Depletion

The Westside drainage variable for depletion, seepage loss, is described below.

Seepage Loss

CALSIM II depletion, *D620Accr,* is assigned to seepage loss SL639, using the GIS grid.

Module Methodology

CALSIM II determines the quantity of seepage loss and the EC value, which is equal to CALSIM II node 620 outflow salinity, using the link-node approach. **Table A-3** of **Appendix A** shows disaggregation details.

NON-PROJECT DIVERSION

The Water Quality Module disaggregates each CALSIM II non-project diversion to multiple non-project diversions. (Details are given in the module methodology section.)

CALSIM II Variable		Westside drainage variable
Non-project diversion (D)	=	Σ Non-project diversion (NPD)

CALSIM II non-project diversions are aggregated diversions of non-CVP or non-SWP contracts, including riparian, pre-1914, and post-1914 appropriative diversions. Along the San Joaquin River between Lander Avenue and Vernalis, four CALSIM II non-project diversion arcs occur; their assumed coverage is shown in **Table 3-5**.

Table 3-5. CALSIM Non-Project Demand Diversions and Corresponding CALSIM Non-Project Return Flows

CALSIM II Non-Project Diversion Arc	CALSIM Non-Project Return Arc	Assumed Coverage in River Miles
D620B	R630M	84 ~ 133
D630B	R637D	75 ~ 84
D637	R639A	73 ~ 75
D639	no return	

Westside Drainage Variable for Non-Project Diversion

Each CALSIM II non-project diversion is disaggregated into multiple Westside drainage non-project diversions.

Non-Project Diversion

In Water Quality Module, the total of Westside drainage non-project diversions over a river reach is equal to the corresponding CALSIMII diversion. But SJRIO assumptions for non-project diversion locations and allocation pattern were used to improve spatial resolution.

In SJRIO, there are two kinds of non-project diversions: (1) post-1914 appropriation (at 16 diversion points), and (2) riparian and pre-1914 appropriation (at 22 diversion points). Inputs of annual post-1914 appropriative diversion are based on historical records maintained by the Water Rights Division of the SWRCB (**Table 3-6**). SJRIO also assumed that riparian and pre-1914 diversions are for irrigating pasture, corn, and almonds; water usage is based on crop acreage at each diversion (**Table 3-7**) and year-type irrigation schedule (**Table 3-8**). This module uses dry-year numbers, which are the highest of the four year-types. SJRIO non-project diversions at various river miles and at the corresponding DSM2-SJR node are summarized in **Table 3-6**. Details of SJRIO non-project diversions are contained in the SJRIO2 Documentation and User Manual (1996).

The Water Quality Module does not use the actual number of SJRIO non-project diversions. However, the SJRIO non-project diversions provide the means of allocating CALSIM II non-project diversions to the 24 diversions modeled in DSM2-SJR (**Table 3-6**). SJRIO diversion locations are converted to the DSM2-SJR schematic based on river mile.

Table 3-6. SJRIO Dry Year Non-Project Diversions and Allocation Patterns for Westside Drainage Non-Project Diversions and Returns

SJRIO Dry Year Non-Project Diversion (acre-feet)	Non-Project Diversion			Non-Project Return		
	SJRIO River Mile	DSM2-SJR Node	Allocation Pattern	SJRIO River Mile	DSM2-SJR Node	Allocation Pattern
	CALSIM II Non-Project Diversion: D620B			*CALSIM II Non-Project Return: R630M*		
2,835	130.5	649	4.0%	130.5	649	4.0%
1,701	125.0	645	2.4%	125.0	645	2.4%
2,550	117.0	638	3.6%	117.0	638	7.3%
2,550	115.5	637	3.6%			
4,828	114.6	636	6.9%	113.4	635	6.9%
623	110.5	632	2.9%	109.0	631	9.7%
538	110.1					
867	110.0					
2,891	109.8	631	4.8%			
454	109.2					
253	108.0	630	2.0%			
1,134	107.2					
1,417	106.3	629	2.0%	105.0	628	41.0%
1,417	104.8	628	31.5%			
4,828	104.2					
15,834	104.0					
4,510	103.4	627	7.5%			
723	103.3					
39	98.9	624	2.7%	98.6	623	2.7%
29	98.8					
1,807	98.7					
723	92.2	616	6.8%	92.9	617	6.8%
4,025	92.1					
556	90.9	615	3.2%	91.4	616	3.2%
17	90.5					
1,701	89.6					
148	89.1	614	3.0%	87.0	612	15.9%
1,938	89.0					
1,898	88.7	613	2.7%			
3,282	87.5	612	4.7%			
3,890	86.1	611	5.6%			
	CALSIM II Non-Project Diversion: D630B			*CALSIM II Non-Project Return: R637D*		
2,835	80.2	605	7.5%	80.0	605	7.5%
2,823	79.1	604	7.5%	79.0	604	7.5%
20,958	77.3	603	55.4%	77.4	603	55.4%
11,202	76.0	602	29.6%	76.0	602	29.6%
	CALSIM II Non-Project Diversion: D637			*CALSIM II Non-Project Return: R639A*		
397	75.4	601	100.0%	74.9	601	100.0%
	CALSIM II Non-Project Diversion: D639			*No Return*		
12,878	74.4	17	100.0%			
12,647	74.2					

Riparian and pre-1914 diversions (unshaded)
Post-1914 diversions (shaded)

DRAFT

**Table 3-7. SJRIO Assumption:
Crop Acreage Irrigated by Riparian and Pre-1914 Diversion**

River Mile	Crop Acreage		
	Pasture	Corn	Almonds
130.5	250	250	0
125.0	150	150	0
117.0	75	75	0
115.5	225	225	0
110.5	55	55	0
110.1	47.5	47.5	0
109.2	40	40	0
107.2	100	100	0
106.3	125	125	0
104.8	125	125	0
98.9	3.5	3.5	0
98.8	2.5	2.5	0
90.5	1.5	1.5	0
89.6	150	150	0
89.1	13	13	0
89.0	247	28	0
88.7	242	27	0
87.5	419	47	0
86.1	0	0	1264
80.2	250	250	0
79.1	249	249	0
75.4	35	35	0

Source: SJRIODAY2K\DPMP.DAT

Table 3-8. SJRIO Assumption: Dry-Year Irrigation Schedule by Crop Types

Month	Crop Demand (inches)		
	Pasture	Corn	Almonds
Oct	4.39	0	0
Nov	0	0	0
Dec	0	0	0
Jan	0	0	0
Feb	0	0	0
Mar	4.75	0	0.02
Apr	11.64	0	8.05
May	12.08	0	7.48
Jun	14.15	12.62	6
Jul	16.39	20.26	7.48
Aug	15.23	12.62	6.46
Sep	10.09	1.8	1.44

Source: SJRIODAY2K\HRPMP.DAT

Module Methodology

Water Quality Module methodology for non-project diversion is shown in **Figure 3-8** and equation 3-7 through 3-9.

For each CALSIM II non-project diversion, Water Quality Module functions as followed:

1. Determine coverage of each CALSIM II non-project diversion in river mile.

2. Identify all SJRIO non-project diversions within that river reach.

3. Use equation 3-7 to calculate the total SJRIO non-project diversion amount at each DSM2-SJR node. For example, R630West corresponds to 31 SJRIO diversions, which can be aggregated to 18 DSM2-SJR nodes.

4. Use equation 3-8 to calculate the SJRIO non-project diversion weight based on diversion amount under DSM2-SJR schematic within that river reach.

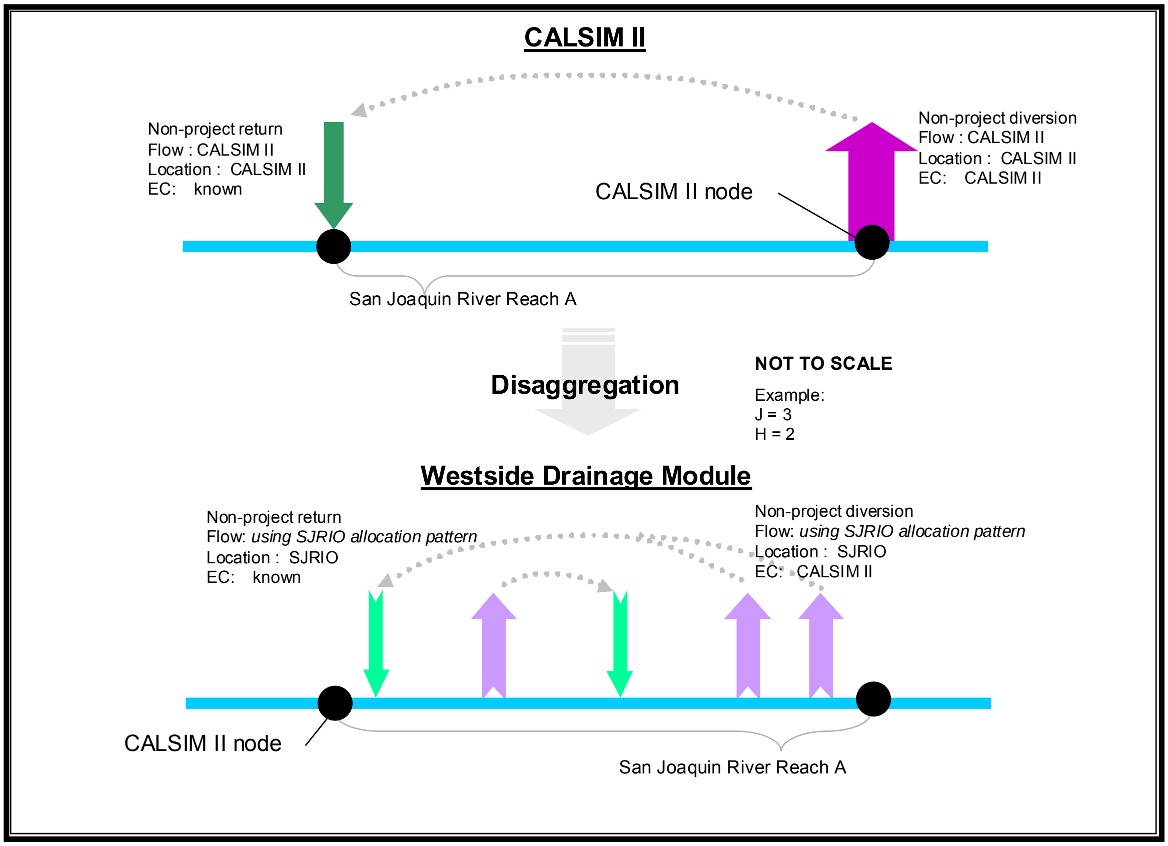
(Steps 1 through 4 are a pre-process. Diversion weights were calculated before running the model and values are stored in the lookup table *DSM2_NPD.table*.)

5. Use equation 3-9 to calculate the monthly flow of each Westside drainage non-project diversion.

6. Write the disaggregated flows from Step 5 and their EC values to an output file. EC values are from salt balancing along the San Joaquin River; all Westside drainage non-project diversions of the same reach have the same EC value.

Table A-4 of **Appendix A** summarizes the disaggregation of CALSIM II non-project diversions along the San Joaquin River.

Figure 3-8. Water Quality Module Methodology: Non-Project Diversion and Return



$$Q^{A}_{(DN,j)} = \sum_{k=1}^{K} Q^{j}_{(SN,k)} \qquad 3\text{-}7$$

$$w_D(A,j) = \frac{Q^{A}_{(DN,j)}}{\sum_{m=1}^{M} Q^{A}_{(DN,j)}} \qquad 3\text{-}8$$

$$Q^{A}_{(NPD,j)} = Q^{A}_{D} \times w_D(A,j) \qquad 3\text{-}9$$

where

A	=	Reach A of San Joaquin River
D	=	CALSIM II non-project diversion arc
NPD	=	Westside drainage non-project diversion arc
DN	=	Aggregated SJRIO non-project diversion arc under DSM2-SJR schematic
SN	=	SJRIO non-project diversion arc
K	=	Total number of SJRIO non-project diversion arcs
J	=	Total number of Westside drainage non-project diversion locations
Q^{A}_{D}	=	Monthly flow rate of CALSIM II non-project diversion in reach A
$Q^{A}_{(NPD,j)}$	=	Monthly flow rate of Westside drainage non-project diversion at the j^{th} location in reach A

$Q^{A}_{(DN,j)}$ = Monthly flow rate of the lumped SJRIO diversion at the j[th] location in reach A

$Q^{j}_{(SN,k)}$ = Monthly flow rate of the k[th] SJRIO diversion local creek inflow at the j[th] location

$w_D(A,j)$ = Diversion weight at the j[th] location of reach A

NON-PROJECT RETURN FLOWS

The Water Quality Module disaggregates one CALSIM II non-project return to multiple non-project returns. (Details are provided in the module methodology section.)

CALSIM II variable		Westside drainage variable
Non-project return (R)	=	Σ Non-project return (NPR)

Along the lower San Joaquin River, each CALSIM non-project demand diversion has one non-project return flow. CALSIM II assumes that 30 percent of the non-project diversions return to the San Joaquin River as non-project return (from "*Return-table.wresl*" file). As for its source, the coverage of CALSIM II non-project return is over a river reach (**Table 3-5**).

Westside Drainage Variable for Non-Project Returns

The Westside drainage variable for non-project return flows is multiple non-project returns.

Non-Project Return

The 3 CALSIM non-project returns are disaggregated into15 Westside drainage non-project return flows. The application of the SJRIO assumption for non-project return is similar to SJRIO non-project diversion, to provide the allocation pattern (**Table 3-6**) and thus increase the spatial resolution of CALSIM II non-project return. CALSIM II governs the flow quantity.

SJRIO assumed that 30 percent of each non-project diversion drains back to the San Joaquin River. **Table 3-6** summarizes the return path from Table 8 of Appendix C for Regulation of Agricultural Drainage to the San Joaquin River (SWRCB, 1987) and the allocation pattern for each CALSIM II return.

Module Methodology

The disaggregation methodology of the Water Quality Module for non-project diversions and returns is very similar, as described in the previous section. The major methodology difference is in calculating EC. According to current agricultural practice, diverted San Joaquin River water is first mixed with other water sources, and then applied to farmlands. Since proportions of water sources are unknown, it is assumed that salinity of non-project returns is independent of source quality. In this module, EC values of non-project return are an input time-series. The module uses equation 3-13 to calculate the resultant EC value of CALSIM II non-project return; this value is then used in salt balancing along the San Joaquin River. **Table A-5** of **Appendix A** summarizes the disaggregation of CALSIM II non-project return.

$$Q^{A}_{(DN,h)} = \sum_{k=1}^{K} Q^{h}_{(SN,k)} \qquad 3\text{-}10$$

$$w_R(A,h) = \frac{Q^A_{(DN,h)}}{\sum_{m=1}^{M} Q^A_{(DN,h)}} \tag{3-11}$$

$$Q^A_{(NPR,h)} = Q^A_R \times w_R(A,h) \tag{3-12}$$

$$EC^A_R = \sum_{h=1}^{H} \left\{ Q^A_{(NPR,m)} \times w_R(A,h) \right\} \tag{3-13}$$

where

A	=	Reach A of San Joaquin River
R	=	CALSIM II non-project return arc
NPR	=	Westside drainage non-project return arc
DN	=	Aggregated SJRIO non-project diversion arc under DSM2-SJR schematic
SN	=	SJRIO non-project diversion arc
K	=	Total number of SJRIO non-project diversion arcs
H	=	Total number of Westside drainage non-project return locations
Q^A_R	=	Monthly flow rate of CALSIM II non-project return in reach A
$Q^A_{(NPR,h)}$	=	Monthly flow rate of Westside drainage non-project return at the h^{th} location in reach A
$Q^A_{(DN,h)}$	=	Monthly flow rate of the aggregated SJRIO diversion at the h^{th} location in reach A
$Q^h_{(SN,k)}$	=	Monthly flow rate of the k^{th} SJRIO diversion local creek inflow at the h^{th} location
EC^A_R	=	EC value of CALSIM II non-project return of reach A
$w_R(A,h)$	=	Return weight at the h^{th} location of reach A

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CHAPTER 4. WATER QUALITY PARAMETERS

This chapter documents another key component of the Water Quality Module, the water quality parameters for salt balancing. These parameters depend on flow type, time and, location. In the module, EC is used as the water quality parameter for the San Joaquin River flow between Lander Avenue and Vernalis because Vernalis water quality objectives in the 1995 WQCP are measured in EC. This chapter discusses the following topics:

- Methodology of EC development
- Details of EC assumptions
- Module results compared to historical records (in form of EC-flow relationships)
- Effects of change in parameters

REVISED SAN JOAQUIN RIVER HYDROLOGY

EC selection in the Water Quality Module hinged on hydrology development of the SJR Package. In 2004, the SJR Package updated CALSIM II system operations, flow routing, inflow time-series, and delivery logic for the San Joaquin River basin. This section summarizes the updates to a degree sufficient to understand EC selection in the Water Quality Module; details can be found in the SJR Package documentation (Reclamation, 2004).

During flow development in the SJR Package, the San Joaquin River between Lander Avenue and Vernalis was divided into three reaches for flow balancing. Within each reach, logic or time-series for returns, diversions, and tributary flows were developed based on analyses of historical records. Under the conservation of flow, total outflows equal total inflows; one accretion (or net river gain, the total of river gains and losses over a reach) was used to maintain the monthly flow balance (equations 4-1 to 4-3).

Because the Water Quality Module further disaggregates each accretion into one local creek inflow, multiple tile drainages, and multiple groundwater base flows; the local creek inflow becomes the flow balance closure term in the module (equation 4-4).

$$\Sigma Q_{outflow} = \Sigma Q_{inflow} \qquad \text{4-1}$$

$$Q_{downstream} + \Sigma Q_{diversion} = Q_{upstream} + \Sigma Q_{return} + \Sigma Q_{tributary} + Q_{accretion} \qquad \text{4-2}$$

$$Q_{accretion} = Q_{upstream} + \Sigma Q_{return} + \Sigma Q_{tributary} - Q_{downstream} - \Sigma Q_{diversion} \qquad \text{4-3}$$

$$Q_{accretion} = \Sigma Q_{T,D} + \Sigma Q_{BF} + Q_{CI} \qquad \text{4-4}$$

Where

$Q_{downstream}$ = Downstream flow of the reach

$Q_{diversion}$ = Diversion along the reach

$Q_{upstream}$ = Upstream flow of the reach

Q_{return} = Return flow along the reach

$Q_{tributary}$ = Tributary inflow along the reach

$Q_{accretion}$ = Accretion (net river gain) for the entire reach

Q_{TD} = Tile drain at a location

Q_{BF} = Groundwater base flow at a location

Q_{CI} = Local creek inflow for the entire river reach

METHODOLOGY FOR SELECTING WATER QUALITY PARAMETERS

Salt balancing in the Water Quality Module assumes the following:

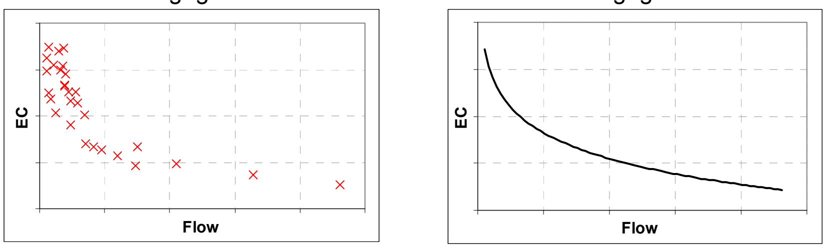
- EC is a surrogate water quality indicator
- Salt load is a product of EC in microSiemen per centimeter (µS/cm) and flow rate in cubic feet per second (CFS)
- Inflow salt load is equal to outflow salt load within each river reach (conservation of salt load
- Perfect mixing of inflows (that is, outflows are all of the same water quality)

The biggest problem in assigning representative water quality parameters is insufficient water quality measurements. To overcome this problems, two major groups of EC values are assumed. The first group, for non-local creek flows (that is all Westside drainage flows except local creek flows), was developed from the most recent water quality information (historical records, previous studies, and assumptions in existing publicly released models). The second group of EC values, for local creek inflows, was determined through calibration performed from upstream to downstream due to the lack of water quality data. Once the first group of EC values is established, EC values for local creek inflows were calibrated until the module gave an EC-flow relationship similar to the historical trend at the gage location. The calibration procedure is illustrated in **Figure 4-1** and **Table 4-1** summarizes EC assumptions in the Water Quality Module.

Figure 4-1. EC Calibration Steps for Local Creek Inflow in Water Quality Module

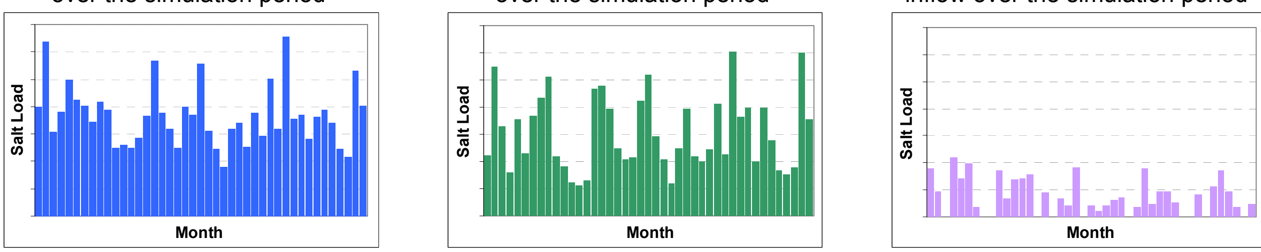
1. At the downstream end of a river reach, use historical gage records to determine the best fit regression equation to represent the historical EC-flow relationship at the gage.

EC-flow relationship: historical gage records — Best fit regression equation: historical gage records



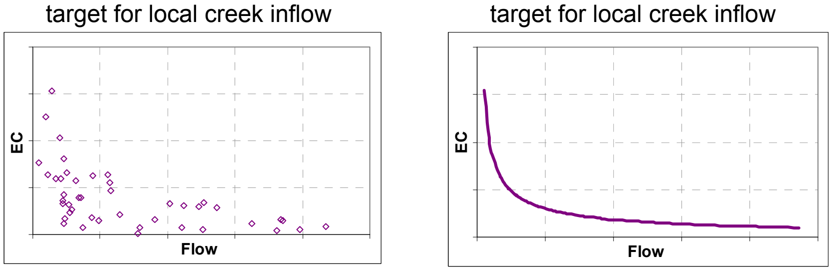
2. Each month, obtain the salt load target at the gage through the regression equation in Step 1. Calculate the total salt load from non-local creek flows within the river reach. Subtract the latter from the former to obtain the targeted monthly salt load from local creek inflow.

Salt load target at gage over the simulation period - Salt load from non-local creek flows over the simulation period = Salt load target from local creek inflow over the simulation period



3. For local creek inflow, the monthly salt load targets over the simulation period provide the EC-flow relationship. Determine a regression equation to best fit this relationship.

EC-flow relationship: target for local creek inflow — Best fit regression equation: target for local creek inflow



4. Apply and iterate the regression equation from Step 3 in CALSIM II to give an EC-flow relationship at the gage best fitting the historical. (This is the calibration process.)

EC-flow relationship: CALSIM II results vs. gage records

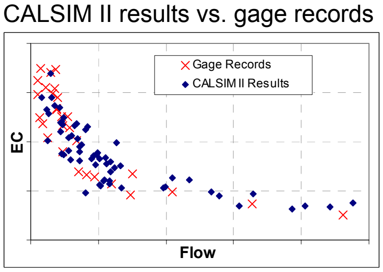


Table 4-1. Summary of EC Assumptions in Water Quality Module

Flow Types	Sources of EC Input
Non-Local Creek Flows	
Tributaries	
San Luis Drain	Grassland Bypass Project Monitoring Data (Oct 97 to Sep 03)
Mud/Salt Slough base flow	Grassland Bypass Project Monitoring Data (Oct 97 to Sep 03)
VAMP flows from Exchange Contractors	TMDL Report (CVRWQCB 2002a)
San Joaquin River at Lander Avenue	TMDL Report (CVRWQCB 2002b)
Merced River near Stevinson	TMDL Report (CVRWQCB 2002b)
Tuolumne River near Modesto	TMDL Report (CVRWQCB 2002b)
Stanislaus accretions	CALSIM II (September 30, 2002)
Eastside Returns	
From Modesto irrigation districts	CALSIM II (September 30, 2002)
From Tuolumne irrigation districts	CALSIM II (September 30, 2002)
Westside Returns	
From pumped groundwater usage	SJRIO (2003 version)
From DMC water usage	SJRIO (2003 version)
Non-Project Returns	SJRIO (2003 version)
Within Accretions	
Tile drainage	SJRIO (2003 version)
Base flow	SJRIO (2003 version)
Local Creek Flows	*Calibration against historical records*

EC ASSUMPTIONS FOR NON-LOCAL CREEK FLOWS

Non-local creek flows include San Luis Drain, Mud/Salt Slough, VAMP flows from Exchange Contractors, San Joaquin River flow at Lander Avenue, Eastside tributaries (Merced, Tuolumne, and Stanislaus rivers), Eastside returns, Westside returns, non-project returns, tile drainages, and base flows. EC assumptions for these flows were developed from the following:

- Monitoring data from Grassland Bypass Project (water years 1997 to 2003)
- Previous 2002 CVRWQCB study
- Model assumptions in CALSIM II Benchmark Studies (September 2002)
- Model assumptions in SJRIO (2003 version)

Source 1: Grassland Bypass Project

Grassland Bypass Project[14] Quarterly Data Reports from October 1996 to September 2003 provide historical daily records of flow rate and quality at Stations B and F, which are discharges from San Luis Drain and Salt Slough at Highway 165, respectively. In the Water Quality Module, monthly average EC values for Stations B and F (**Table 4-2**) were used as the

[14] Grassland Bypass Project is an interagency program. Participants include Reclamation, CVRWQCB, U.S. Fish and Wildlife Service, California Department of Fish and Game, San Luis & Delta-Mendota Water Authority, U.S. Environmental Protection Agency, U.S. Geological Survey, and San Francisco Estuary Institute.

assumed EC for CALSIM II inflows SLD_614 and I614A,[15] respectively, and repeat every year. Such monthly EC values are for all year types.

Source 2: CVRWQCM TMDL Report

In January 2002, CVRWQCB released the staff report Total Maximum Daily Load for Salinity and Boron in the Lower San Joaquin River, or TMDL Report (CVRWQCB, 2002a). The TMDL Report used historical records (from October 1992 to September 1997) to obtain year-typed monthly averages of the total dissolved solids (TDS) concentration for DMC Reach 3 Check 21; these averages represent the water quality of flows from Mendota Pool. TDS numbers in Table 4-18 of the TMDL Report (CVRWQCB, 2002a) were converted to EC[16] (through dividing by 0.62) to represent the water quality of VAMP flows contributed by the Exchange Contractors, through CALSIM II arc C607BVAMP, in the Water Quality Module (**Table 4-2**).

Appendix A of the TMDL Report (CVRWQCB, 2002b) included regression equations for TDS-flow relationships at major monitoring stations in the San Joaquin Valley and their TDS-to-EC conversions. In the Water Quality Module, these regressions provided EC values for flows of the San Joaquin River at Lander Avenue, Merced River near Stevinson, and Tuolumne River near Modesto (**Table 4-3**); these flows correspond to CALSIM II arcs C611, C566, and C545, respectively.

Source 3: CALSIM II Benchmark Studies (September 2002)

CALISM II Benchmark Studies dated September 30, 2002, have default EC values for Eastside returns and Stanislaus River flow at Ripon (**Table 4-2**). Because salinity values for these Eastside flows are not widely available, the CALSIM II default values are used in the Water Quality Module.

Source 4: SJRIO (2003 Version)

SJRIO uses TDS as a water quality parameter for inflows of the San Joaquin River from water years 1977 to 2000. SJRIO TDS values depend on timing, flow type, and location; some values were applied in the Water Quality Module in a similar manner.

According to the SJRIO definition, there are four SJRIO year types: wet, normal, dry, and critical; water years 1982, 1979, 1985, and 1981 are their representative years, respectively (**Table 4-4**). SJRIO year-types for water years 1921 through 2000 were identified and shown in **Table A-9** in **Appendix A**. In the Water Quality Module, it is assumed that the year-type SJRIO water quality inputs were applied to the 77-year simulation period (water years 1922 to 1998).

In the Water Quality Module, three types of SJRIO water quality inputs, "SUB," "GW," and "SRF," were applied to tile drainage, groundwater base flow, Westside returns (from DMC water and groundwater), and non-project returns (**Table 4-5**). Since water from different sources is mixed before irrigation, the current stage assumed all surface returns from agricultural irrigation are of the same water quality. Also, for the same flow type, SJRIO water quality varies along

[15] In CALSIM II, inflow arc I614 is a summation of SLD_614 (San Luis Drain) and I614A (combined Mud and Salt sloughs). In reality, San Luis Drain discharges into Mud Slough, then Mud Slough into the San Joaquin River. Since flow allocation of I614A among Mud and Salt sloughs is not identified, water quality data of Salt Slough are applied to I614A.

[16] The TDS-to-EC conversion factor is from page 73 of CVRWQCB 2002a.

the San Joaquin River, so do Westside flows in the Water Quality Module. **Table A-10** in **Appendix A** lists all SJRIO TDS inputs used in the Water Quality Module.

SJRIO TDS inputs for the uncalibrated mode[17] were converted to EC for the Water Quality Module. Although the TDS-EC relationship varies with location, in the current parameter development, a uniform TDS-to-EC conversion factor[18] of 1.538 was used. Location-dependent conversion factors should be developed as part of future EC input enhancement. **Figure 4-2** shows the average, maximum, and minimum EC assumptions. A few SJRIO outputs were missing for certain months, and linear interpolation was used to replace the missing values.

Table 4-2. EC Assumptions for Non-Local Creek Flows

CALSIM Arc	Description	San Joaquin Valley Year Type	EC (µS/cm) Oct	Nov	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep
Source1: Grassland Bypass Project														
I614A[1]	Mud/Salt Slough	All	1,174	1,384	1,615	1,779	1,617	1,577	1,577	1,327	1,120	954	926	1,078
SLD_614[2]	San Luis Drain	All	4,419	4,356	4,420	4,512	4,492	5,113	5,316	4,885	4,663	4,261	3,853	4,050
Source 2: CVRWQCB TMDL Report														
C607BVAMP[3]	VAMP flow from Exchange Contractors	Wet	390	527	508	611	577	527	423	390	423	410	468	416
		Above Normal	418	418	381	368	502	461	592	576	534	432	516	574
		Below Normal	548	618	602	427	618	663	652	600	542	508	563	690
		Dry	679	818	824	487	734	863	711	626	550	584	608	806
		Critical	897	942	1,047	916	944	926	758	740	827	856	852	866
Source 3: CALSIM II Benchmark Studies														
R620, R630J, R630K, R630L R636A, R636B, R636C, R528A, R528B, R528C, R637A, R637B, and R637C	Eastside returns	All	380	380	380	380	380	190	190	190	190	190	190	190
C520	Stanislaus River below Goodwin	All	85	85	85	85	85	85	85	85	85	85	85	85
I528	Accretion at Ripon	All	380	380	380	380	380	190	190	190	190	190	190	190

Note:
[1] Station F daily monitoring data, Grassland Bypass Project Quarterly Data Reports (Oct 1996 to Sep 2003)
[2] Station B daily monitoring data, Grassland Bypass Project Quarterly Data Reports (Oct 1996 to Sep 2003)
[3] Mendota Pool Reach 3 Check 21 of Table 4-18 in CVRWQCB, 2002a

[17] There are two modes in SJRIO: uncalibrated and calibrated. The uncalibrated mode uses inputs to calculate mass balance (for flow and salt); besides mass balance, the calibrated mode calibrates inputs against gage data.
[18] The TDS-to-EC conversion factor (1/0.65 = 1.538) is from page 13 of the SJRIO Documentation and User Manual (CVRWQCB, 1996).

Table 4-3. Assumptions for EC-Flow Relationship: San Joaquin River at Lander Avenue, Merced River near Stevinson, and Tuolumne River near Modesto

Ln (TDS) = A * Ln(Flow) + B
EC = C * TDS

Flow (acre-feet)	Description	A	B	C
C611	San Joaquin River at Lander Avenue	-0.356	8.9038	1.56
C566	Merced River near Stevinson	-0.385	8.4386	1.52
C545	Tuolumne River near Modesto	-0.4164	9.0859	1.49

Note: Flow is in acre-feet. EC is in μS/cm.
Source: Figure A-1 and Tables A-2 and A-3 in CVRWQCB, 2002b

Table 4-4. SJRIO Representative Hydrologic Year-Type

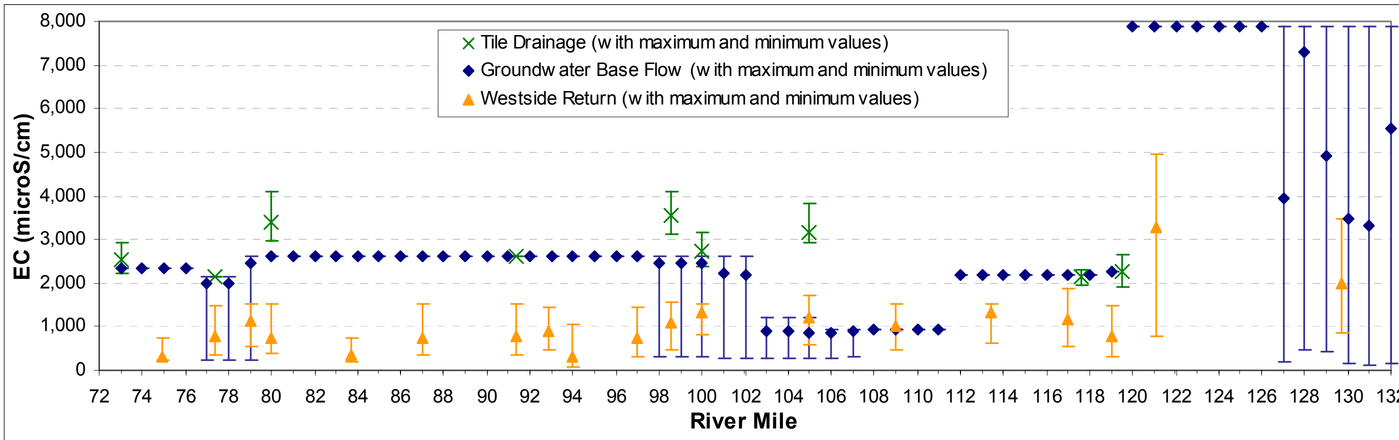
SJRIO Year-Type	Water Year
Wet	1982
Normal	1979
Dry	1985
Critical	1981

From SJRIO file HWSF.dat

Table 4-5. Year-Type SJRIO Water Quality Inputs Applied to Westside Flows in Water Quality Module

SJRIO Flow Types	SJRIO Description	Westside Flows in Water Quality Module
SUB	Subsurface agricultural drainage	Tile drainage
GW	Groundwater accretion/depletion	Groundwater base flow
SRF	Surface agricultural discharge	Westside returns from using groundwater Westside returns from using DMC water Non-project return

Figure 4-2. EC Assumptions from SJRIO for Tile Drainage, Groundwater Base Flow, and Westside Return (in Monthly Average, Maximum, and Minimum Values)



Note: Westside return includes Westside groundwater return, Westside surface water return, and non-project return.

EC Calibration: Local Creek Inflows

After EC assumptions for non-local-creek flows were established, EC for local creek inflow was calibrated to best fit CALSIM II EC-flow relationships at gage locations with the historical. In the current stage, calibrations were taken against Newman gage records first, and then Vernalis. Historical EC-flow relationships at Newman and Vernalis were developed prior to the EC calibration of local creek inflow.

Historical EC-Flow Relationship at Newman and Vernalis

USGS and CVRWQCB have a number of major monitoring gage stations along the San Joaquin River between Lander Avenue and Vernalis. However, the CALSIM II schematic only explicitly represents three of these gages: Newman, Maze, and Vernalis. These three gages have records for different time periods (**Table 4-6**). Per discussion with the SJR Package team and CVRWQCB, recent historical records should be used to reflect recent operations coded in CALSIM II. It is assumed that only gage records after May 1985 for Newman and Vernalis were used in the EC calibration of local creek inflow because of the following:

- Completion of New Melones Reservoir on Stanislaus River has led to enormous changes in water supply operations along the San Joaquin River, and it was initially filled in 1983.

- Gage records began to overlap in May 1985.

- Insufficient records exist from the Maze gage for statistical analysis (less than 4 years of records after May 1985).

Through statistical analysis, historical EC-flow relationships at Newman and Vernalis were represented by regression equations (**Table 4-7**) that assume second-order polynomial for the logarithm of EC against the logarithm of flow (except for Vernalis in February, which shows a strong inverse linear relationship). Without a large amount of records, Newman has only one

EC-flow relationship for all months; however, Vernalis has one EC-flow relationship for each month. At Newman, one regression can best fit the historical EC-flow relationship for the entire year, while at Vernalis, each month has its own equation to address its distinctive characteristic.

In the CALSIM II schematic, nodes 620 and 639 are labeled as Newman and Vernalis, respectively. CALSIM II variables C639 and VERNWQFINAL were used to represent Vernalis gage flow and EC; however, CALSIM II node 620 does not truly represent Newman. This is because the Newman gage is directly downstream of the confluence of the Merced River with the San Joaquin River, and no diversions or returns occur within such short distance. In other words, CALSIM II diversion arcs D620A and D620B and channel C619 should be incurred downstream of Newman gage (**Figure 4-3**). Therefore, CALSIM II results were post-processed to explicitly represent Newman gage flow and EC, as follows:

$$\text{Newman flow} = \text{C614} + \text{R620} + \text{C566} + \text{I620} - \text{D620Accr} \qquad \text{4-5}$$

$$\begin{aligned}\text{Newman EC} = {} & (\text{C614} * \text{EC\_614\_Final} \\ & + \text{R620} * \text{EC\_E\_Return620} \\ & + \text{C566} * \text{EC\_566\_Final} \\ & + \text{I620} * \text{EC\_I620}) / \\ & (\text{C614} + \text{R620} + \text{C566} + \text{I620}) \qquad \text{4-6}\end{aligned}$$

Table 4-6. Gage Records for Calibration of the Water Quality Module

Gages Along San Joaquin River	Available Records	Records Used for Calibration	Sources	Corresponding CALSIM Flow	Corresponding CALSIM EC	Calibration Target
Newman	May 85 - Sep 98	May 85 - Sep 98	Monthly average from CVRWQCB	Post-processed	Post-processed	I620
Maze	Oct 76 - Mar 89	None	Monthly average from CVRWQCB	C636	EC_636_Final	None
Vernalis	Dec 2, 50 - Sep 11, 02	May 14, 85 - Sep 11, 02	Daily records from USGS	C639	VERNWQFINAL	Total local creek inflow in I636 and I637

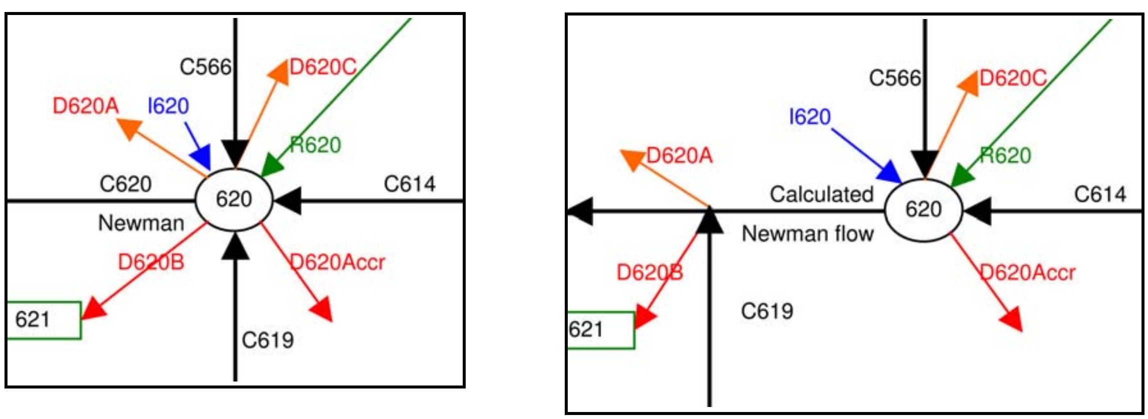
Table 4-7. EC Assumptions:
Regression Equations for Historical EC-Flow Relationship at Newman and Vernalis

$\log_{10}(EC) = A * [\log_{10}(Flow)]^2 + B * \log_{10}(Flow) + C$			
Period	**A**	**B**	**C**
Newman			
All months	-0.1426	0.5416	2.8934
Vernalis			
October	-0.9695	5.5591	-5.0185
November	-0.3447	1.5709	1.3623
December	-0.0898	-0.0022	3.7887
January	-0.5562	3.2143	-1.6741
February	0.0000	-0.6670	5.1506
March	-0.1948	0.7693	2.5694
April	-0.1643	0.7409	2.1874
May	-0.1398	0.5011	2.6324
June	-0.2561	1.0951	1.9675
July	-0.1798	0.6633	2.5595
August	-0.0933	0.2117	3.1175
September	-0.2368	0.9417	2.2191

Note:
EC is in µS/cm. Flow is in CFS.

Figure 4-3. EC Assumptions:
Representation of Newman in CALSIM II and EC Calibration

(a) CALSIM II **(b) EC Calibration**



Calibration Approach

EC for local creek inflows was calibrated to best fit module EC-flow relationships at Newman and Vernalis with historical relationships. In the Water Quality Module, it is assumed that the logarithm for EC is inversely linear with the logarithm of the local creek inflow rate; **Table 4-8** summarizes the EC-flow regression equations obtained from calibration.

Calibration steps to develop an EC-flow regression equation for local creek inflow within I620[19] are as follows:

1. From the regression equation for the historical Newman EC-flow relationship, determine the Newman EC target and then the Newman salt load target based on CALSIM II Newman flows for each month.

2. For each month, subtract the salt load from non-local creek flows from the Newman target to obtain the salt load target and then the EC target for local creek inflow.

3. Assume a regression equation for local creek inflow, Log (EC in µS/cm) = A - B* Log (flow in CFS), to best fit with all EC targets in the entire simulation period. Determine coefficients A and B by the least square error of Log EC. Also use an EC cap on local creek inflow is also used to avoid overloading during low-flow period.

EC calibration begins from upstream (Newman) to downstream (Vernalis). After I620, two more local creek inflows must be calibrated; they are within accretion arcs I636 (for the reach between Newman and Maze) and I637 (for the reach between Maze and Vernalis). Since the SJR Package assumed that I636 has 95 percent of total monthly accretion between Newman and Vernalis while I637 has the remaining 5 percent, the Water Quality Module assumes that local creek inflows within I636 and I637 are of the same water quality. EC for total local creek inflows within I636 and I637 were calibrated against Vernalis historical records only, bypassing the Maze gage. The calibration procedure is similar to I620, except that it requires some iterations to converge. This is because Reclamation is required to meet water quality objectives at Vernalis[20] through releases from New Melones Reservoir; changes in EC for local creek inflow will alter the amount of Stanislaus River flow into the San Joaquin River and thus alter EC at Vernalis. Since there is 1 historical EC-flow regression equation at the Vernalis gage for each month, it is intuitive to have 12 EC-flow regressions for local creek inflow within I636 and I637 to provide a higher temporal resolution.

[19] Based on the CALSIM II flow assumption, net river gain for river reach between Mud Slough and Newman is I620 minus D620Accr (both have positive values). Positive river gains go to I620 while the negative values go to D620Accr. It is assumed that no tile drainage or groundwater base flow exist in this reach. Since there are months I620 with zero flow rates (meanwhile D620Accr with flow), using I620 directly in the EC-flow relationship for local creek inflow would mean that no salt enters the river from accretion. However, this is not true; although flows into the river are less than flows away, salt does enter the river. To avoid underestimating salt load, (I620+D620Accr) and (2*D620Accr) are used in the EC-flow relationship and salt balancing, instead of I620 and D620Accr.

[20] The maximum 30-day running average of mean daily EC at Vernalis is 700 µS/cm for April through August and 1,000 µS/cm for September through March.

Table 4-8. Regression Equation for EC-Flow Relationship of Local Creek Inflow

$Log_{10}(EC)$ = Minimum { $Log_{10}(Cap)$, A - B * [$Log_{10}(Flow)$] }			
Period	**A**	**B**	**Cap**
Newman to Mud Slough			
All months	4.759	0.545	4,500
Vernalis to Newman			
October	5.973	1.265	1,200
November	6.158	1.315	1,200
December	3.943	0.459	1,000
January	5.426	1.061	600
February	6.072	1.275	200
March	4.510	0.673	200
April	4.154	0.502	1,200
May	4.840	0.763	1,200
June	5.456	0.980	1,200
July	5.002	0.757	1,500
August	6.976	1.545	1,500
September	6.114	1.236	1,500

Note:
EC is in µS/cm. Flow is in CFS.

RESULTS

A 77-year D-1641 single study of CALSIM II with the Water Quality Module was performed. Month-by-month EC-flow relationships for CALSIM II results at Newman, Maze, and Vernalis are compared to historical gage records in **Figure 4-4**.

Within the same month, from upstream to downstream, EC for the San Joaquin River decreases while river flow increases due to Eastside inflows of lower EC. EC-flow relationships from CALSIM II results at all three locations generally have captured the historical trend. Although Maze gage records were not used for calibration, modeling results show a good fit with Maze historical trends for all months. At Vernalis, CALSIM II results also followed the historical EC-flow relationships, except that the module tends to overestimate EC in February and March due to EC assumptions for boundary conditions. (This anomaly is explained further in the next section.)

CALSIM II is constrained to maintain Vernalis EC below 700 µS/cm in April through August and below 1,000 µS/cm in remaining months. These requirements can only be violated when the New Melones Reservoir is out of water supply. With the Water Quality Module, CALSIM II has tried to meet the requirement each month, shown in **Figure 4-4** as a horizontal line formed by a number of dots at the corresponding EC requirements. Under the original modified Kratzer equation, EC at Maze is only related to flow quantity through regression (**Table 4-9**), not water composition; therefore, all EC-flow dots fell on a single curve (**Table B-1** in **Appendix B**). **Table 4-10** shows the statistical analysis of the number of Vernalis EC violations from the Water Quality Module and Krazter equation after contributions from New Melones Reservoir. In July and August, the modified Kratzer equation resulted in a large number of violations, which contradicts reality. The Water Quality Module improved the EC estimate.

Figure 4-4. EC-Flow Relationships at Vernalis, Maze, and Newman: CALSIM II Results Compared to Historical Gage Records

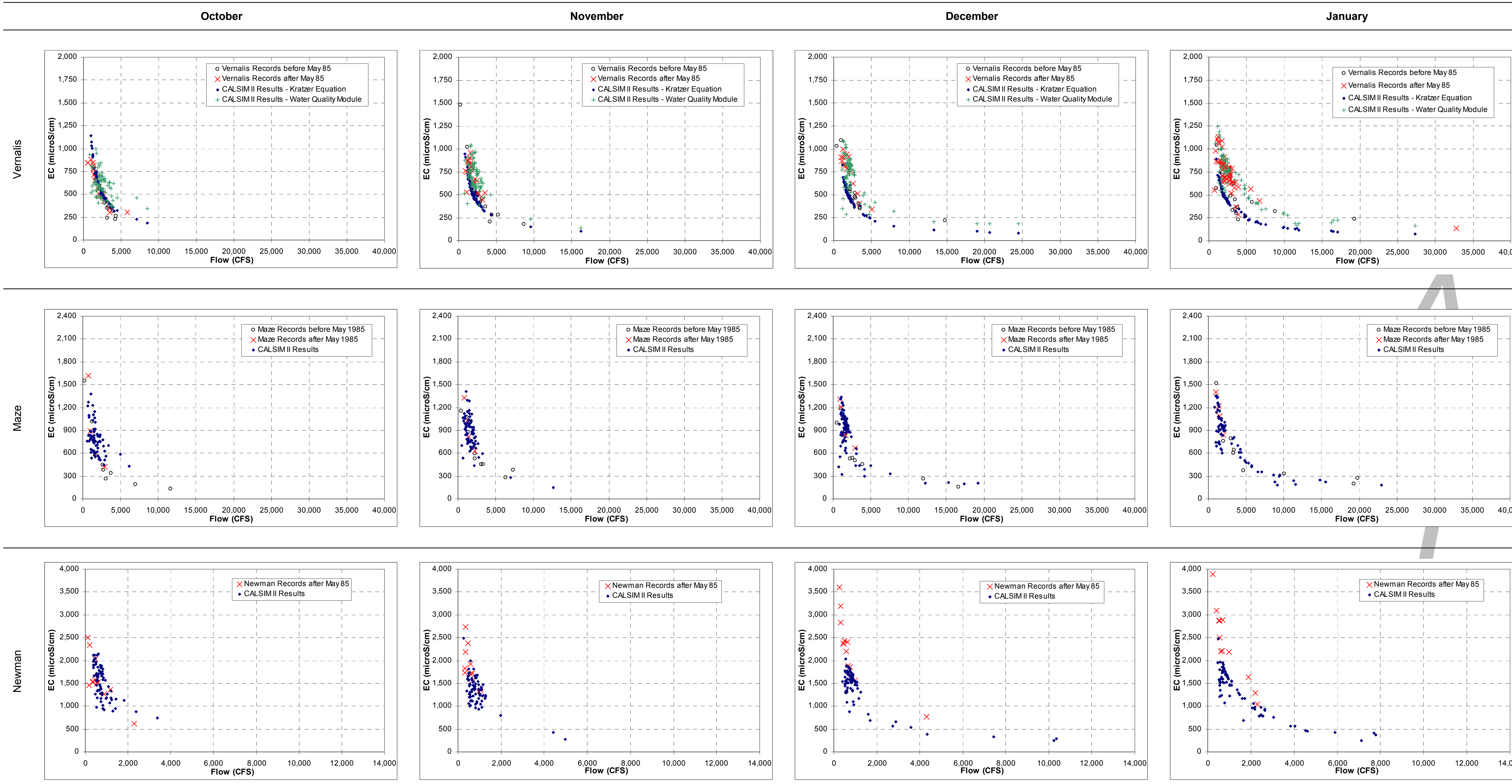


Figure 4-4. EC-Flow Relationships at Vernalis, Maze, and Newman: CALSIM II Results Compared to Historical Gage Records (Cont.)

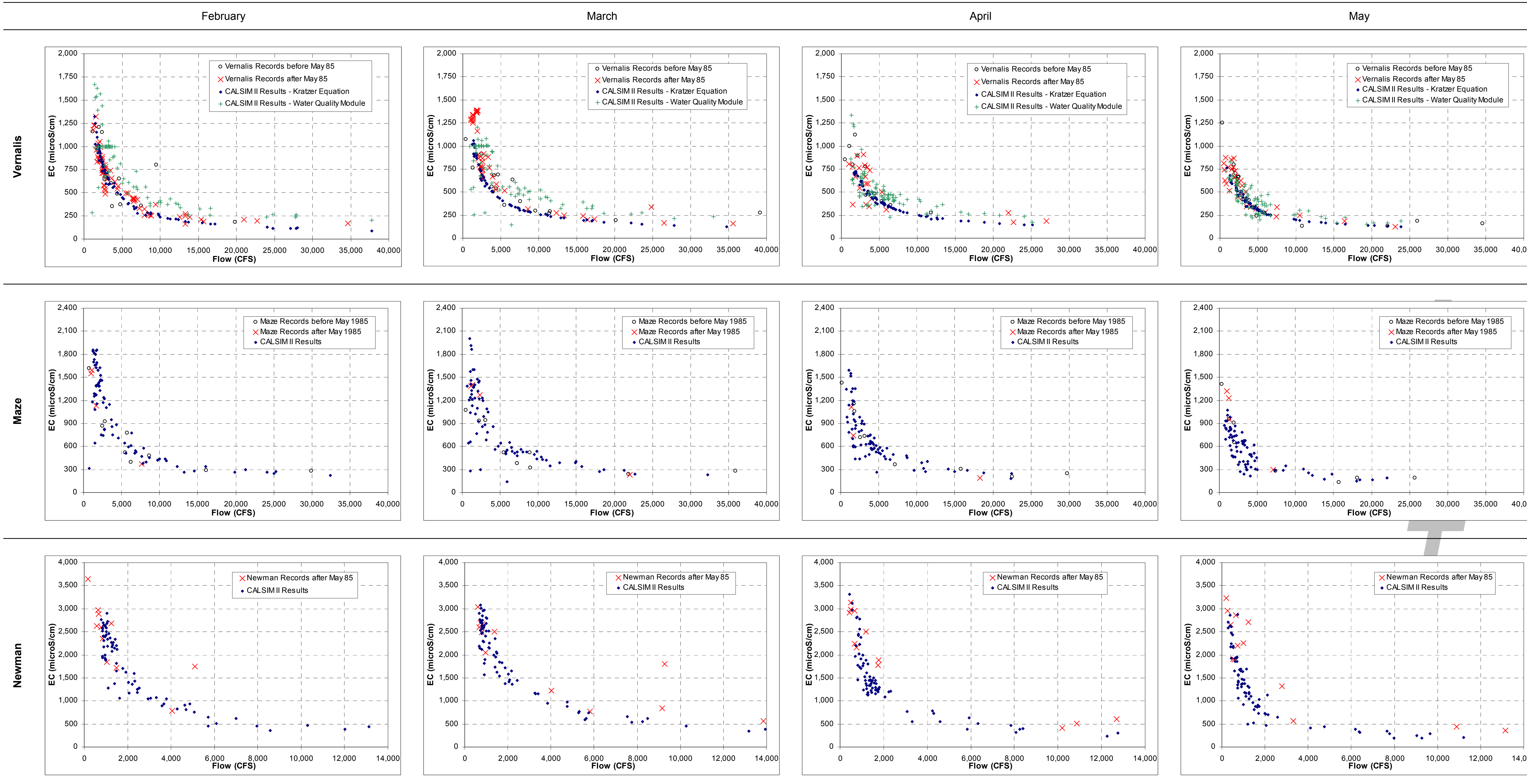


Figure 4-4. EC-Flow Relationships at Vernalis, Maze, and Newman: CALSIM II Results Compared to Historical Gage Records (Cont.)

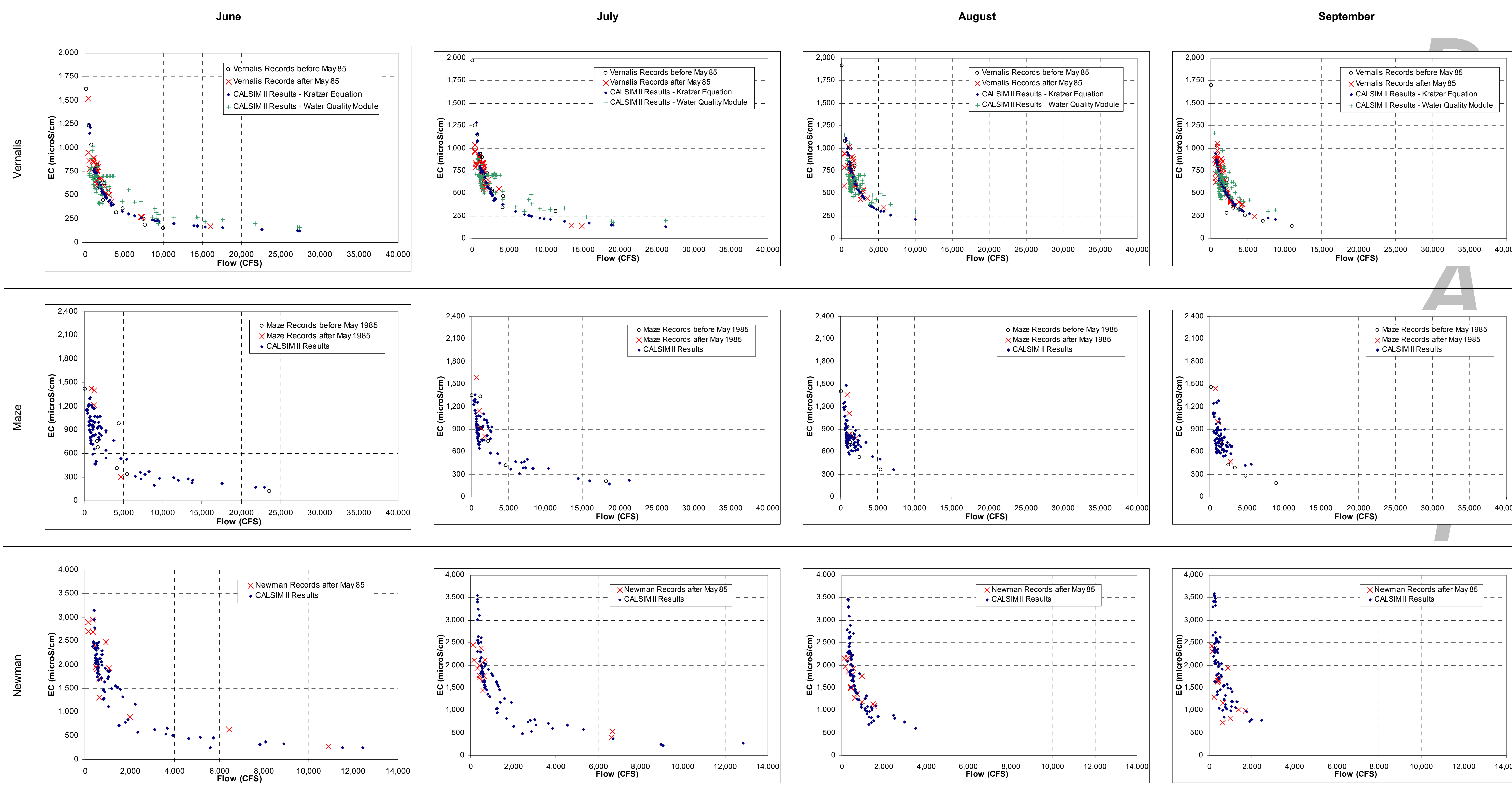


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Table 4-9. CALSIM II Assumption: Modified Kratzer Equation for EC-Flow Relationship at Maze

Mainstem EC = A * (Mainstem Flow in acre-feet)^ B		
Period	**A**	**B**
Irrigation season		
March through September	54,645	-0.44346
Non-irrigation season		
October through February	86,6201	-0.69289

Note:
EC is in µS/cm.
Mainstem flow = C637 + C528 + R630West + R639B + C619 + R614West + I614

Table 4-10. Number of Months with Violations of Vernalis Water Quality Requirements (during 77 simulation years)

Vernalis EC Mechanism in CALSIM II	Oct	Nov	Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep
Water Quality Module	1	2	5	5	10	15	7	1	6	6	5	1
Krazter Equation	4	0	0	0	12	12	0	1	8	34	27	0

Note: From D-1641 single-study results

DISCUSSION ON PARAMETER SELECTION

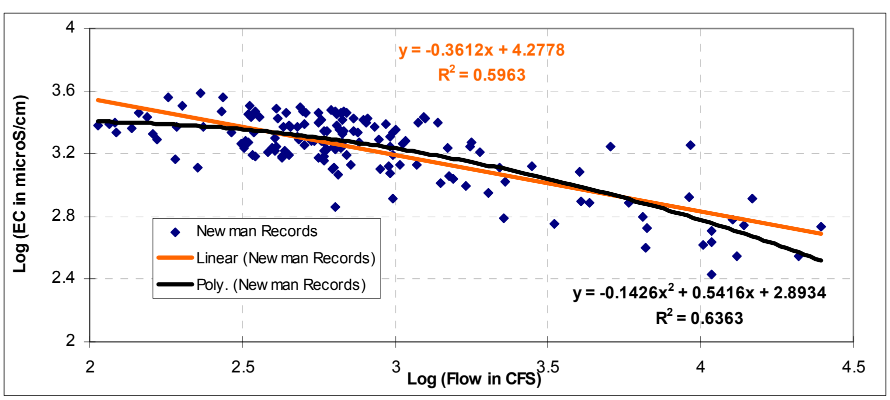
EC-flow relationships at Newman, Maze, and Vernalis are highly dependent on EC assumptions in the Water Quality Module. This section discusses about the effect of changing these assumptions.

Historical EC-Flow Relationship for Gage Records: Linear vs. Polynomial

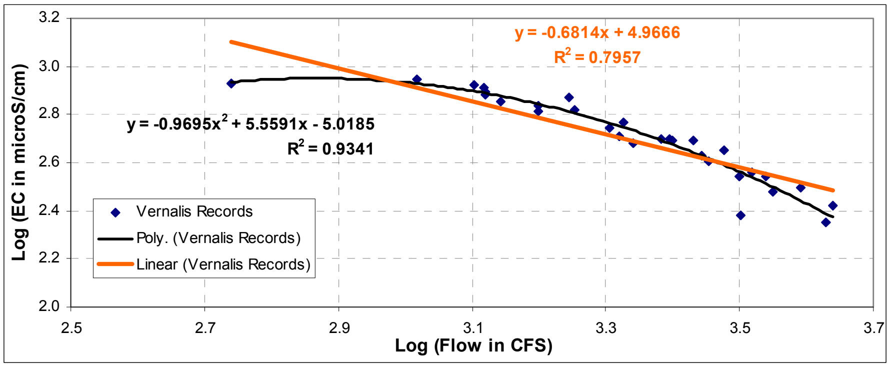
Figure 4-5 shows historical EC-flow relationships for Newman and Vernalis (October is used as an example) in both linear and second-order polynomial regressions of the logarithm for EC against the logarithm for flow. In both cases, the R-square of polynomial regression is higher than the linear because the second-order polynomial regression provides a better EC prediction, especially for avoiding overestimates under low-flow conditions.

Figure 4-5. EC-Flow Relationship for Newman and Vernalis Gage Records

(a) Newman: All Records



(b) Vernalis: October Records



Salt Load from Local Creek Inflow

Due to the assumed calibration approach, EC for local creek inflow acts as the closure term to best fit historical EC-flow relationships at Newman and Vernalis. The Log(EC)-Log(Flow) regression equation for local creek inflow is highly dependent on EC assumptions for non-local creek flows. Conditions of zero salt loads from local creek inflow can depict the flexibility of adjusting the corresponding EC to best fit model results with historical EC-flow relationships. **Tables B-2 through B-4** in **Appendix B** summarize the EC-flow relationship at Newman, Maze, and Vernalis with zero salt loads from local creek inflow.

Figure 4-6 shows the EC-flow relationship at Newman (January is used as an example) with zero salt loads from local creek inflow between Lander Avenue and Newman. The big difference between the “with” and “without” trends shows that there is high flexibility in changing EC for local creek inflow to best fit modeling results with historical trends. **Figure 4-7** shows the EC-flow relationship at Vernalis (using February and March as examples) with zero salt loads from local creek inflow between Lander Avenue and Newman. The insignificant difference between the “with” and “without” conditions indicate that high-background EC led to overestimating EC even without salt from local creek inflow. There is little flexibility for adjusting EC of local creek inflow to enhance the EC estimate. To eliminate systematic EC overestimates would require changing EC assumptions for non-local creek flows.

Figure 4-6. EC-Flow Relationship at Newman in January: Zero Salt Loads from Local Creek Inflow Between Lander Avenue and Newman

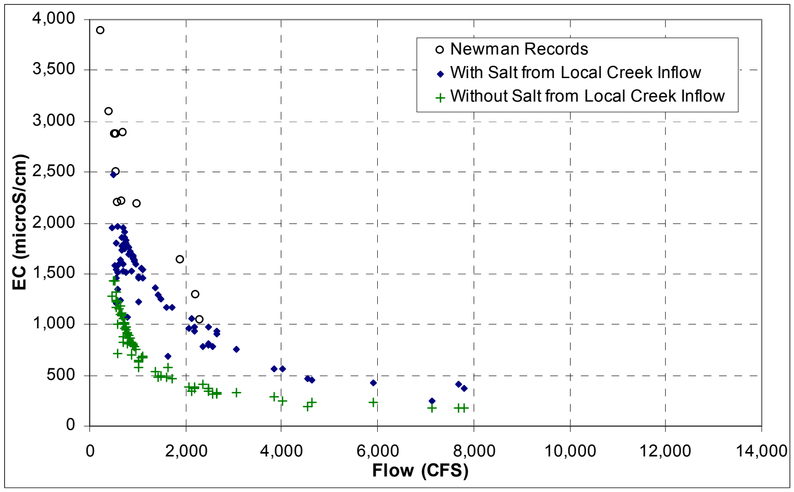
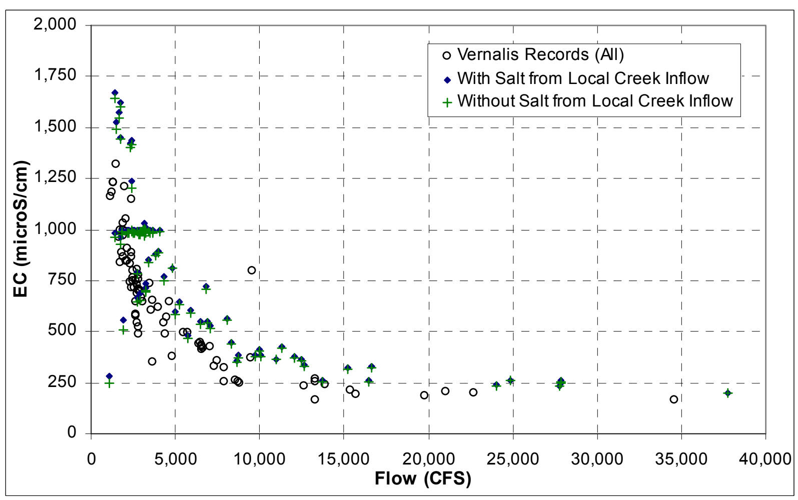
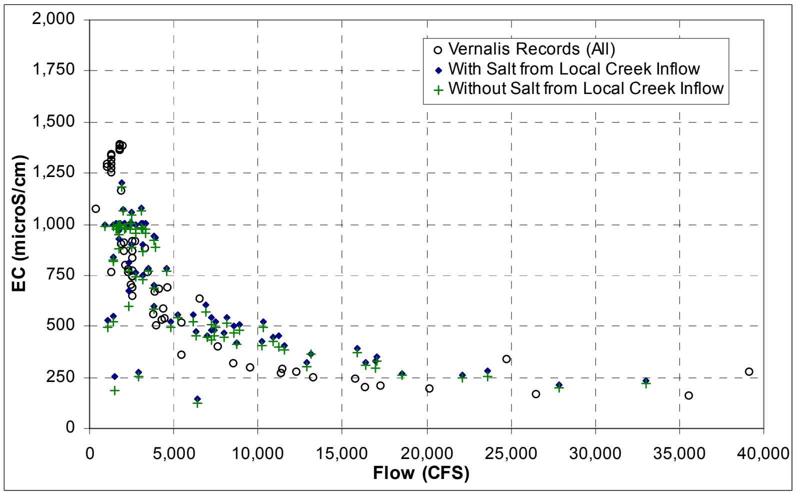


Figure 4-7. EC-Flow Relationship at Vernalis in February: Zero Salt Loads from Local Creek Inflow Between Newman and Vernalis

(a) February



(b) March

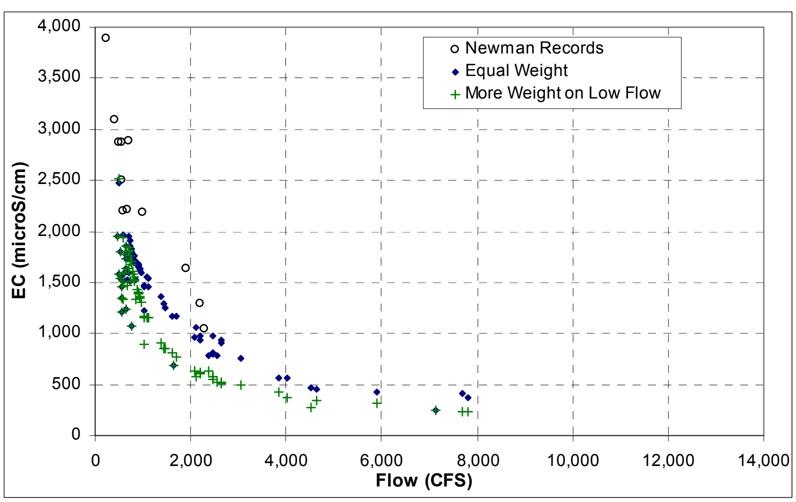


Low Flow Emphasis

Based on historical records, low-flow conditions always accompany high EC conditions, which is a major ongoing water quality concern. Emphasizing low-flow conditions might address this concern; it was achieved through Step 3 of EC calibration for local creek inflow: instead of logarithm for EC, the least square error of EC was taken. The resulting regression equation would focus on low-flow conditions, which have greater weight in the calibration (the lower the flow, the higher the EC and weight).

A model run for low flow emphasis at Newman was performed; the January results of EC-flow relationships are shown in **Figure 4-8**. For conditions with flow rate below 700 CFS, Newman EC values from both approaches are the same. However, with higher flow rates, the low-flow emphasis approach gave a lower than historical EC value. The low-flow emphasis did not change water quality estimates of low flows but did sacrifice the EC estimate for high-flow conditions.

Figure 4-8. EC-Flow Relationship at Newman in January: More Weight on Low Flow



Variance in SJRIO Parameter

Water years 1979, 1981, 1982, and 1985 are representative for SJRIO hydrologic year-types. New Melones Dam was completed in 1977 and was initially filled in 1983. Since then, many regulations have been implemented relating to salinity control, instream flow, fish and wildlife protection, and water supply; the California water allocation bigger picture had abruptly changed. Existing Vernalis water quality requirements were stipulated under the 1995 WQCP to ensure adequate flow in the San Joaquin River and to control saline agricultural drainage. Currently, New Melones Reservoir is operated under the 1997 New Melones Interim Operations Plan. Therefore, SJRIO representative years may not reflect existing conditions.

A new set of SJRIO representative year-types was selected from the 1990s (**Table 4-11**). Comparing TDS inputs between these two sets of SJRIO data shows the variance in water quality parameters from SJRIO.

For the “SUB” and “GW” categories, minor differences occur the two data sets. This means SJRIO assumed that the water quality of groundwater is insensitive to operational changes. Also, since the groundwater quantity of tile drainage and groundwater base flow assumed in the Water Quality Module is comparatively small, changing representative years would have no significant effects.

For the “SRF” category, TDS inputs are different for the two representative years of each SJRIO year-type are greater. **Figure 4-9** shows EC differences at river mile 121.1 (Mud Slough, where the majority of Westside return arc R614West occurs) and river mile 97 (Patterson sewage outfall and Olive Avenue drains) as an example. Based on SJRIO assumptions, effluents from Mud Slough in recent years are of higher quality than earlier years while the water quality pattern of Patterson sewage shifted within the year. These SJRIO changes may reflect effects of some of the new regional or local drainage programs (like Grassland Bypass Project or changes in Mendota Pool operation).

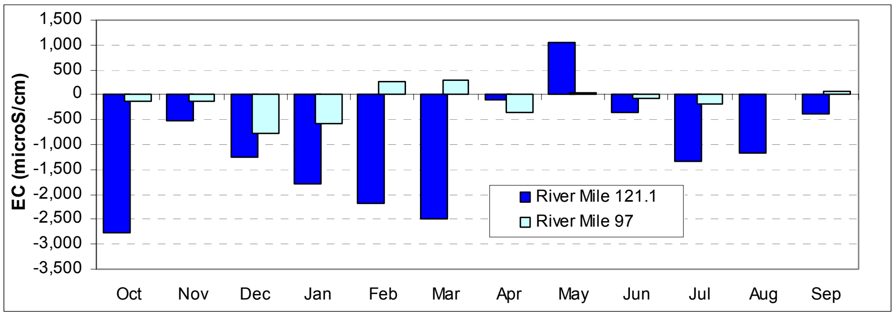
Table 4-11. SJRIO Representative Hydrologic Year Type

SJRIO Year Type	Water Year	
	Original	Recent
Wet	1982	1995
Normal	1979	1999
Dry	1985	1985*
Critical	1981	1994

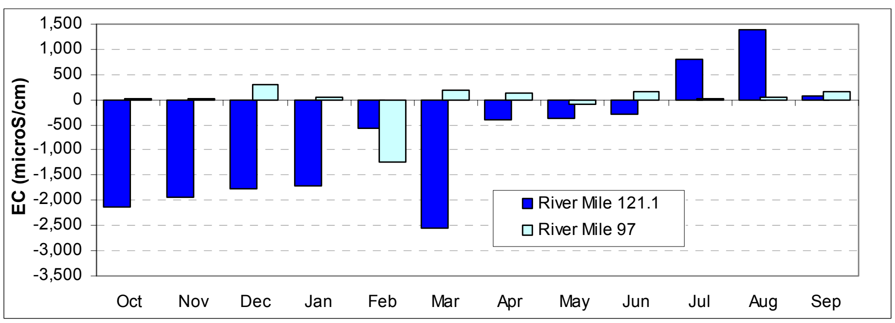
Note: No SJRIO normal year in 1990s.

Figure 4-9. Comparison of SJRIO Water Quality Parameters: "SRF" Surface Agricultural Discharge at River Mile 97 and 121.1

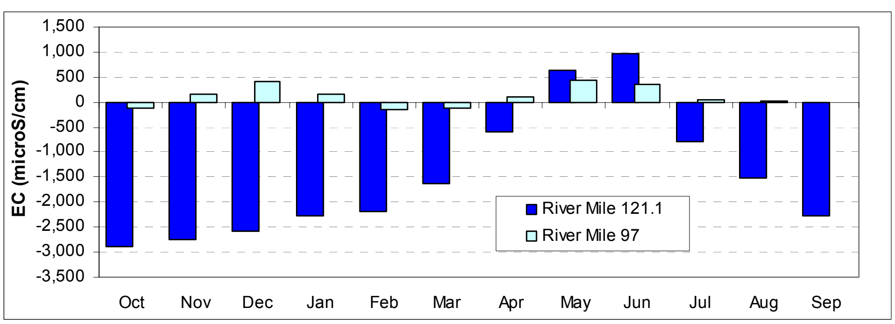
(a) Wet (Water Year 1995 minus 1982)



(b) Normal (Water Year 1999 minus 1979)



(c) Critical (Water Year 1994 minus 1981)



Flow and Salt Load Contribution

Tables B-5 through B-16 in **Appendix B** summarize the long-term average contribution of flows and salt loads (assumed as the product of flow and EC) for each month along the San Joaquin River at Newman, Maze, and Vernalis in CALSIM II for each month. Pie charts inside these tables shows how the weight of different flows and salt loads changes along the San Joaquin River; the charts also indicate the controlling salt contributor at each location.

Using the Water Quality Module results in February (the month with systematic EC overestimates at Vernalis) as an example, at Newman, Westside returns contribute half of the salt load, followed by 30 percent from local creek inflow. Moving downstream to Maze, 34 percent of river flow is from Tuolumne River but 91 percent of the salt load is from upstream (Newman). The Stanislaus River contributes 15 percent of Vernalis flow and 4 percent of Vernalis salt load. The dilution effect from the Stanislaus River is less than for the Tuolumne River because of lower-averaged flow and higher-averaged EC. Through tracing the source, it can be seen that Westside return arc R614West brings in 45 percent (=96 percent * 91 percent * 51 percent) of the Vernalis salt load. Since the Water Quality Module gave a satisfactory EC-flow relationship at Newman, the oversimplified EC-flow relationships for Stanislaus and Tuolumne rivers may not correctly represent the February and March condition.

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CHAPTER 5. SUMMARY

The purpose of the Water Quality Module is to improve the salinity estimate of the San Joaquin River at Vernalis by disaggregating CALSIM II Westside flows into components and by salt balancing along the San Joaquin River to reflect any change in flow combination. An accurate EC estimate at Vernalis in CALSIM II is essential to water resources planning studies because of Vernalis water quality requirements stipulated under D-1641 for regulatory purposes. However, the Water Quality Module is not intended to replace any water quality models along the San Joaquin River.[21]

The Water Quality Module extends study efforts of the Recirculation Study for flow disaggregation and the CALSIM II link-node approach for salinity estimation. This module is built in the CALSIM II updated in the SJR Package with San Joaquin River Basin hydrology and operations modified. Both the SJR Package and Water Quality Module are part of 2004 CALSIM II benchmark studies improvements.

Coverage of the Water Quality Module is along the San Joaquin River between Lander Avenue and Vernalis, and module development consists of two parallel processes:

- **Disaggregation of Westside flows and implementation of salt-balance computations for the San Joaquin River for water quality tracking purposes** – The modified Kratzer equation, a single EC-flow regression at Maze currently used in CALSIM, was replaced with a series of salt-balance calculations from Lander Avenue to Vernalis through disaggregating CALSIM II Westside flows into more refined flow components, and assigning each component a value for EC. This modification provides a dynamic water quality tracking mechanism, which is an important component for better water quality estimates at Vernalis. Implementation is completed and the process is documented in this Technical Memorandum.

  During module development, study teams for the Water Quality Module and the SJR Package closely coordinated their activities and used a consistent model schematic and assumptions for return flow path. EC calculations for the San Joaquin River were dynamic and thus, flexible in accommodating quantitative changes in flow and/or quality due to hydrologic updates (accretion/depletion inputs, land-use estimates, and groundwater usage) or changes in system operation (irrigation operation of individual water districts, reservoir operation, and implementation of water quality standards) in the San Joaquin Valley.

- **Preparation of representative EC values for planning purposes** – Each disaggregated flow component would require an EC value for salt-balance computations. The scattered data and continued changes in operation render this task difficult. Thus, development of EC values under this task order is mainly to establish the framework and methodology that best uses the available information. It was recognized that further improvements are necessary.

[21] Water quality models, like DMS2-SJR and SJRIO, have a much higher spatial resolution than CALSIM II and can provide more detailed water quality simulation along the San Joaquin River. CALSIM II does not accurately represent intermediate locations among Newman, Maze, and Vernalis.

Discussions and meetings were held among study teams for the Water Quality Module and the SJR Package and CVRWQCB to select representative EC values and review module results. An approach consistent with the flow development in SJR Package was used to establish EC assumptions for different disaggregated flows: 1) determine EC for disaggregated flows with water quality information (monitoring data from the Grassland Bypass Project, TMDL report, CALSIM II assumptions, and SJRIO assumptions) and 2) obtain EC for local creek inflow through calibration against historical gage records (Newman and Vernalis gages). The Water Quality Module has shown improvement in estimating water quality along the San Joaquin River; all EC assumptions are documented in this Technical Memorandum.

RECOMMENDATIONS FOR FUTURE WATER QUALITY MODULE IMPROVEMENT

Improving EC assumptions is an ongoing effort. The current stage of the Water Quality Module has improved the water quality estimates at Vernalis in CALSIM II from using the modified Kratzer Equation. However, the module may occasionally overestimate EC in February and March. Several possibilities for these occasionally overestimates were discussed, including the overly simplified flow-EC relationship associated with Eastside tributaries and return, and the assumed operations of refuges and other facilities near Mendota Pool. While the EC development framework in the Water Quality Module has been established, further calibration requires additional efforts. Future improvements in the Water Quality Module could occur in the following stages:

- Short-term improvements:
  - Adjust the San Joaquin River Basin hydrology and operations simulated in CALSIM with the Water Quality Module to further improve the acceptability of San Joaquin River water quality estimates at Vernalis.
- Medium-term improvements:
  - Refine water quality estimates for Eastside tributaries and Eastside agricultural returns.
  - Update representative SJRIO year-type inputs to reflect current operations through using SJRIO assumptions for simulation years after 1990. Conducting further discussions with CVRWQCB to understand SJRIO input development would be helpful in selecting representative water quality parameters.
  - Develop location-dependent EC-TDS conversion factors to replace the general rule of thumb used in the current Water Quality Module.
  - Extend the module's upstream boundary from Lander Avenue to Mendota Pool. This will enable water quality analysis for Mendota Pool operation changes in the Upper San Joaquin River Basin Storage Investigation, and will result in one of the most complex water quality tracking for the San Joaquin Valley.
- Long-term improvements:

- Incorporate Westside groundwater pumping information from WESTSIM (currently in calibration stage) and available groundwater quality information into CALSIM II. Currently, Westside groundwater pumping is a missing component for CALSIM II; incorporation of these data will change the water balance along the San Joaquin River and will require recalibrating CALSIM II and the Water Quality Module.

- Continue field monitoring program and data collection. Analysis of field data will provide addition insight into the modeling effort.

- Recalibrate the Water Quality Module with major changes in modeled San Joaquin River Basin operation, hydrology, and EC assumptions to maintain consistency in historical gage records and overall improvement in modeling resolution.

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CHAPTER 6. REFERENCE

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